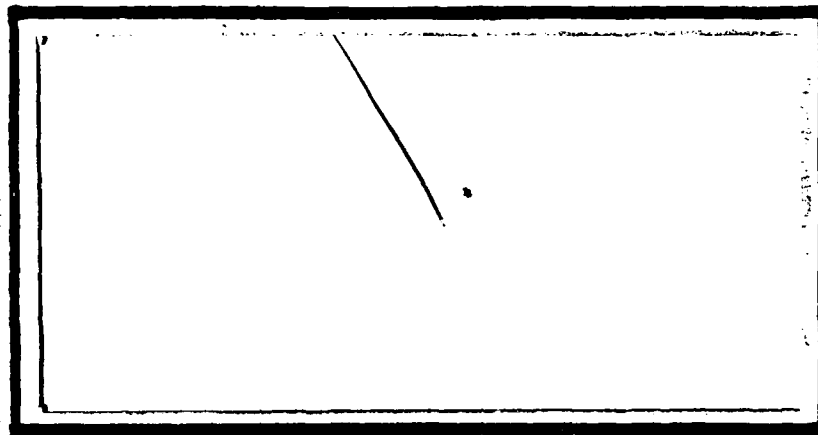


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AFIT/GLM/LSM/88S-8

CASE STUDIES OF SUPPLY  
INVENTORY MODELS

THESIS

William E. Cameron  
Captain, USAF

AFIT/GLM/LSM/88S-8

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CASE STUDIES OF SUPPLY INVENTORY MODELS

THESIS

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology

Air University

In partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Logistics Management

William E. Cameron, B.A.

Captain, USAF

September 1988

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Captain William E. Cameron

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Abstract

The purpose of this thesis was to develop case study examples of Air Force Supply inventory models. It is intended to be a companion work to a previous AFIT thesis, A Handbook of Supply Inventory Models, by Major William C. Hood. Together, these two works are to be used by Air Force Supply personnel to gain an understanding of how the various Supply inventory models work.

These case studies are composed of detailed scenarios which highlight the components and functions of the models presented. All scenarios use Air Force data/situations in their presentation. Following each scenario is a series of questions about the situation presented, or about the model being used, which are designed to increase the understanding and comprehension concerning some aspect of the model's abilities or performance.

The inventory models presented in this study are:

1) the Base-level EOQ model, 2) the AFLC EOQ model, 3) the Repair Cycle Demand Level model, 4) the Multi-Echelon Technique for Recoverable Item Control (METRIC) model, 5) the Dyna-METRIC model, 6) the Manufacturing Resource Planning system, and 7) the bench stock model.

## CASE STUDIES OF SUPPLY INVENTORY MODELS

### I. Introduction

#### Chapter Overview

This chapter provides a general background on the uses of inventory models in the United States Air Force. It also includes sections on: the research problem, investigative questions, the research objectives, and the scope and limitations of the research.

#### Background

In their book, Modern Inventory Management, Prichard and Eagle define inventory management as "the sum total of those activities necessary for the acquisition, storage, sale, disposal, or use of material (23:1)." To accomplish these activities efficiently, a number of mathematical inventory models have been developed and refined over the years. Some of these models are used to determine how much of an item should be stocked or produced by an organization, while others are used to determine if the item should be stocked at all. Many of these inventory models have been adapted for Air Force use and still more have been created specifically for the Air Force.

In the Air Force supply system there are two types of spare part assets: expendable and recoverable spares (15:1). Expendable spares are those that are not designed to be repaired or reused. As they are spent or broken, they are discarded or destroyed. These assets make up approximately 95 percent of a typical base's total line item inventory (4:5-6). Expendable spares are managed in the Air Force through use of Economic Order Quantity (EOQ) inventory models (8:19-52 - 19-56). Recoverable spares are those that are designed to be repaired or reconditioned for subsequent reuse. Though these assets usually comprise only five percent of a base's line item inventory, they can account for 95 percent of the money invested in a base's inventory (4:5-6). Recoverable assets at base-level are managed by the Repair Cycle Demand Level (RCDL) inventory model. The RCDL model calculates how many of a particular spare should be maintained in a base's inventory system, dependent upon the item's historical demand and that particular base's repair capability (6:7). Other models, such as the METRIC model, are used to determine the depot stock levels.

In total, the Air Force has over nine billion dollars invested in expendable and recoverable spares (15:1). The effective use of mathematical inventory models ensures that the Air Force receives the maximum benefit for each dollar spent by efficiently determining inventory requirements.

These models compute the inventory levels needed by each base using the forecasted demand for each individual item.

### Problem Statement

A better understanding of inventory models, both general purpose and Air Force specific, will improve logistician's management of the Air Force inventory system. Today, there are a limited number of comprehensive sources that Air Force supply officers can reference to gain an understanding of the various inventory models and their components. The sources that do exist are primarily concerned with the mathematical formulas, the derivations of these formulas, and the assumptions associated with the different models. Presently, there are no case studies available to demonstrate the techniques and reinforce the concepts of the various inventory models used by the Air Force.

### Investigative Questions

To accomplish research on how the various inventory models are used in the Air Force today, a number of questions need to be addressed. They are designed to build a foundation of knowledge upon which to begin this research study. They start at a very elementary level with an investigation of inventory theory and the basic classical EOQ model, progressing to the more difficult questions and models. The questions to be addressed are:

1. What are the purposes of inventory?
2. What are the components of the classical EOQ inventory model?
3. How does the classical EOQ model translate to the models used by the Air Force to manage expendable items?
4. How do the Air Force EOQ models differ with their implementation level?
5. What are the Air Force specific (recoverable item) models and what are their components?
6. How is Material Requirements Planning (MRP) being used in the Air Force today?

#### Research Objectives

This thesis is intended to be a companion to the work accomplished by Air Force Major William C. Hood, in his master's thesis titled A Handbook of Supply Inventory Models. It is designed to provide Air Force personnel with illustrations of how the Air Force inventory models work using actual Air Force data. The research accomplished for this thesis has three objectives:

1. To provide Air Force personnel with a greater understanding of Air Force expendable inventory models.
2. To provide Air Force personnel with a greater understanding of Air Force reparable inventory models.

3. To provide Air Force personnel with a greater understanding of other miscellaneous Air Force inventory models.

#### Scope and Limitations

1. The research and presentation for expendable item models will be limited to the classical EOQ model and its Air Force counterparts.
2. For reparable items, only those models currently in use or planned will be covered.
3. The miscellaneous models will be limited to the Air Force's use of the Manufacturing Resource Planning (MRP II) inventory system and the bench stock level determination model.
4. Air Force equipment management models will not be covered in this thesis.

#### Organization of the Thesis

The first chapter of this thesis introduces the need for Air Force-based inventory case studies. Chapter II reviews the applicable inventory literature, while Chapter III describes the methodology used to conduct the case studies. Chapter IV is a compilation of case studies highlighting supply inventory models. Each case study is followed by a series of questions. The answering of these questions is intended to provide Air Force supply personnel with an insight into how the models work. Chapter V is a summary of

this research effort. Following Chapter V are three appendixes.

Appendix A is a listing of the inventory-related acronyms and abbreviations used throughout the thesis. It also lists the variable symbols used in the inventory models presented. Appendix B is a listing of the inventory-related definitions. The last section, Appendix C, contains the answers to the questions posed in the case studies of Chapter IV.

## II. Literature Review

### Chapter Overview

This chapter begins with a look at inventory theory and then examines the various inventory models included in this study. The first inventory models examined are the Economic Order Quantity (EOQ) models. This section explores the basic EOQ model and the Air Force variations of the basic model. The next area covered is the Repair Cycle Demand Level (RCDL) model. It is followed by two sections dedicated to recoverable asset models, both backorder-centered and availability-centered models. The final section covers the Material Requirements Planning (MRP) model, looking in particular at the version the Air Force is currently using, Manufacturing Resource Planning (MRP II).

### Inventory Theory

For hundreds of years inventories have been seen as symbols of wealth and power, measured by how many bushels of wheat, heads of cattle, or pounds of gold, for example, a business or nation had stored in their warehouses. Prior to the twentieth century, the costs associated with maintaining large inventories were not a significant factor (28:3). Today that is not true. There are now a number of costs, constraints, and other decision variables that must be considered in determining the best minimum cost inventory levels that a firm should maintain (2:16-24).

One decision a firm must face is whether or not to stock an item. The firm must consider what the item is used for, what are the costs of carrying the item, and what is the risk of the item becoming obsolete. Most importantly, the firm must consider what the value of the item is to their customers (21:150). Another decision for the firm is how much of the item to stock. Today's inventories exist because supply and demand cannot be perfectly matched. So, the firm must consider what functional category the inventory is to serve and what service levels they wish to maintain. The functional categories (purposes) of inventories are: as working stock, safety stock, anticipation stock, pipeline stock, and decoupling stock (31:7).

There are also constraints that a firm must consider when deciding whether to stock an item or when questioning how much to stock. The firm must consider its space constraints (available facilities) as well as the additional personnel that may be required to maintain the stock. Will more or different material handling equipment be required? Lastly, the firm must consider the capital costs of the inventory level they desire. These are the investment costs required to stock the item (31:13).

The costs associated with creating and maintaining inventories must also be considered. First, there is the initial purchase price of a stocked item. To this must be added the cost to order the item from a supplier. This is

the expense involved in processing the order for the item, the costs to conduct follow-up queries that may be required, and the costs involved in actually receiving and storing the item upon its arrival (34:21). There are also carrying costs to be determined. These are the costs associated with stocking the item. They include storage costs, insurance costs, and taxes. The final cost that the firm must consider is, what is the cost of not stocking the item. Are the lost sales or mission degradation worth the cost (31:13-15)?

The Air Force too, must consider the costs and constraints associated with inventory management. This is why a number of inventory models have been created and implemented over time. These models provide the framework to better control the overall inventory system. There are models used to determine what the stockage levels (how much to stock) for an item should be. There are also models used to decide what order quantities best minimize system costs. These models can also be used to determine how often and when we need to place our orders.

Finally, in the Air Force inventory system there are also models used to control reparable assets. Reparable assets are those items that can be repaired or reconditioned and returned to a serviceable condition for reuse (33:581). These models are used to determine what quantities of an item need to be maintained in the inventory system to ensure operational capabilities are sustained and backorders

minimized. These models take into consideration an item's repair time, in addition to its demand history, when computing an item's optimum stock level.

### Economic Order Quantity (EOQ) Models

The Deterministic EOQ Model. One of the objectives of inventory management is to minimize the total cost of the logistics activities (30:403). One means of attaining this minimized cost is through the use of an EOQ inventory model. The classical EOQ model's primary objective is to minimize total variable inventory costs per year. The cost trade-offs required to achieve the most economical order quantity are shown graphically in Figure 1 (30:405). The classical EOQ model is based on the following assumptions:

1. The demand rate is known and constant.
2. The lead-time is known and constant.
3. The entire lot size is added to inventory at the same time.
4. No stockouts are permitted; because demand and lead-time are known, stockouts can be avoided.
5. The cost structure is fixed; order/setup costs are the same regardless of lot size, holding cost is a linear function based on average inventory, and no quantity discounts are given on large purchases.
6. The item is a single product; It does not interact with any other inventory items (there are no joint orders) (31:94).

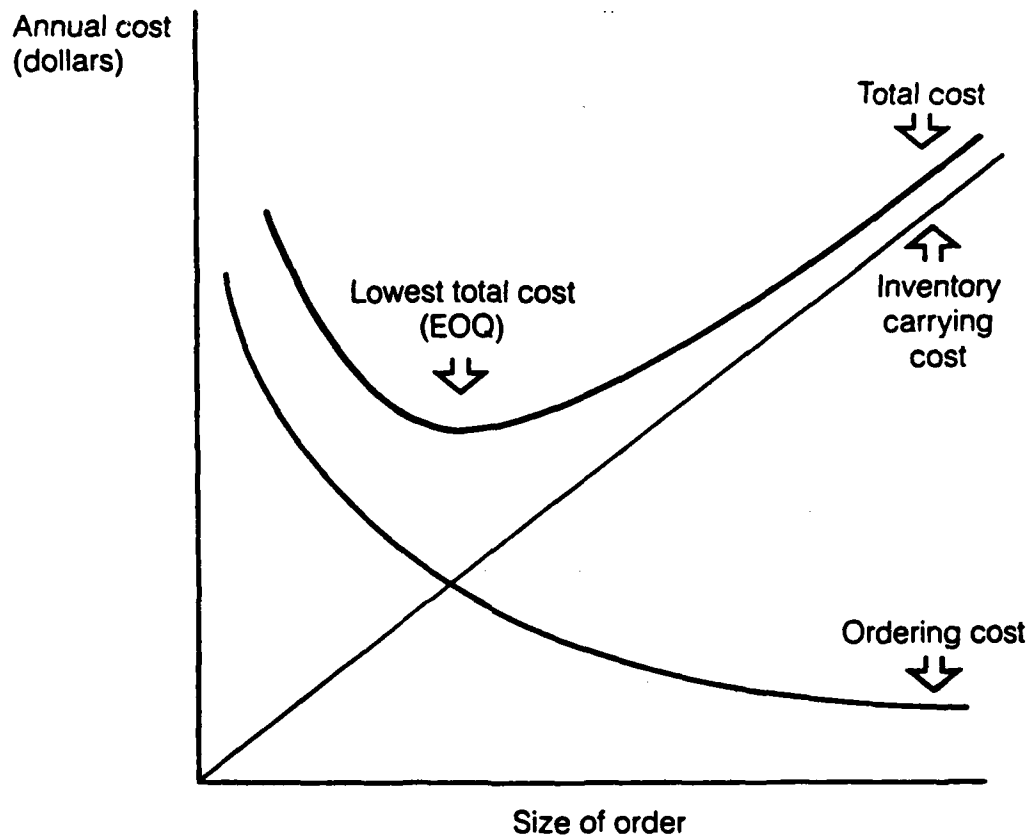


Figure 1. EOQ Total Cost Curve (30:405)

Figure 2 is the idealized situation where  $Q$  is the order size. The downsloping line represents constant demand drawing the inventory level down. An order is placed when the on-hand stock falls to zero if replenishment orders arrive instantaneously. Otherwise, an order is placed when on-hand stocks drop to  $R$  (the reorder point) if the lead-time for the item is greater than zero. When  $Q$  units arrive a lead-time later, the cycle begins anew. The cost formulas associated with the basic EOQ model are:

$$\begin{aligned}\text{Annual carrying cost} &= \text{Average inventory level} * \text{carrying cost} \\ &= (Q/2) * C_H C_U\end{aligned}\tag{2.1}$$

$$\begin{aligned}\text{Annual ordering cost} &= \text{Orders per year} * \text{order cost} \\ &= (D/Q) * C_0\end{aligned}\tag{2.2}$$

$$\begin{aligned}\text{Annual variable total cost} &= \text{Annual carrying cost} + \\ &\quad \text{Annual order cost} \\ TC &= (Q/2) * C_H C_U + (D/Q) * C_0\end{aligned}\tag{2.3}$$

where

- $D$  = Annual demand for the item (units per year)
- $Q$  = Quantity of items ordered at each order point
- $C_H$  = Cost of carrying one unit in inventory for one year
- $C_0$  = Average cost of completing an order for an item
- $C_U$  = Purchase cost of the item
- $TC$  = Total annual variable costs for stocking an item.

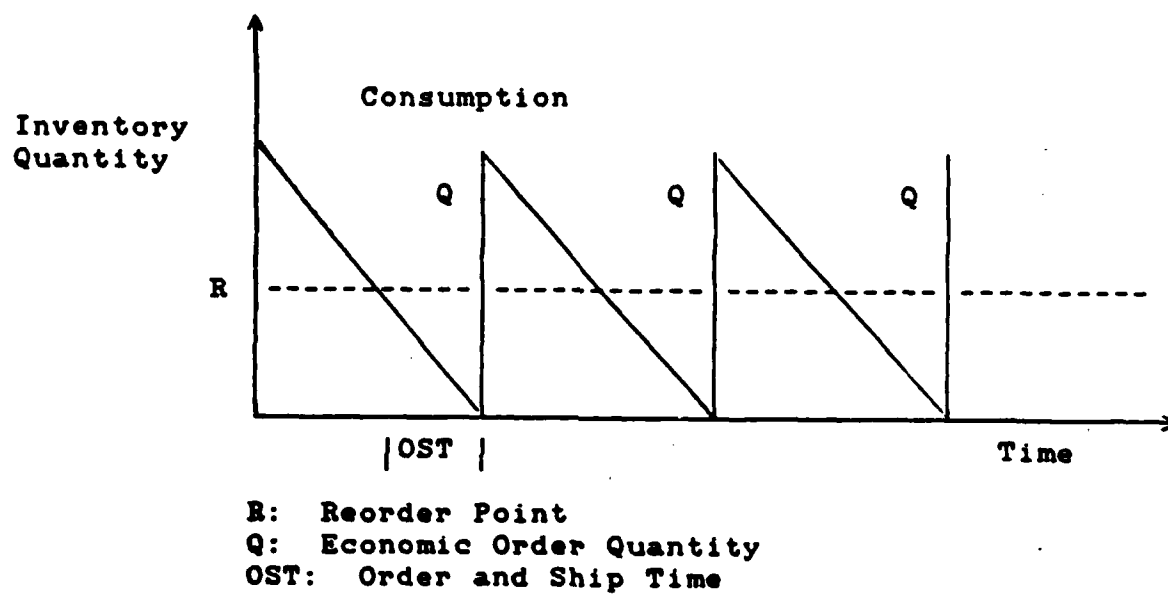


Figure 2. Classical Inventory Model (15:11)

The optimal order quantity is equal to the minimum point on the total cost curve (see Figure 1). The minimum point is determined by setting the total cost equation equal to zero and taking the first derivative and solving for Q. The result of these calculations is the basic EOQ formula (13:479).

$$Q^* = \sqrt{\frac{2DC_0}{C_H C_U}} \quad (2.4)$$

Once the EOQ has been determined, the reorder point (R) and average order interval (T) can be determined by using the following formulas:

$$R = (D * OST) / N \quad (2.5)$$

$$T = D / Q^* \quad (2.6)$$

where

N = The number of operating days per year

OST = Order and Ship Time (in days).

Backorder Costs. A backorder is an unsatisfied demand to be filled later. If there were no costs associated with incurring backorders, no inventories would be held. Conversely, if the costs of stockouts were too expensive, then very large inventories would be held to ensure against the stockouts. In actuality, the backorder costs a firm must face will fall in between the two extremes. Because of this,

sometimes backorders are acceptable toward the end of an order cycle. Examples of the costs associated with backorders are:

1. The costs of expediting orders,
2. Use of an alternative, more expensive source (31:95).

Now, all of the previous assumptions of the classical EOQ model still hold true except for:

1. Stockouts are allowed to happen.
2. All shortages are filled from the next lot quantity shipment (31:95).

With backorders added to the EOQ inventory model, the optimum formulas become:

$$TC = D \cdot C_U + C_O * (D/Q) + C_H C_U * (V^2/2 \cdot D) + C_B \left( \frac{(Q - V)^2}{2D} \right) \quad (2.7)$$

$$Q = \sqrt{\frac{2DC_O}{C_H C_U}} * \sqrt{\frac{C_H C_U + C_B}{C_B}} \quad (2.8)$$

$$V = \sqrt{\frac{2DC_O}{C_H C_U}} * \sqrt{\frac{C_B}{C_H C_U + C_B}} \quad (2.9)$$

$$R = \left( \frac{D * OST}{N} \right) - (Q^* - V) \quad (2.10)$$

where

$V$  = Maximum inventory level in units

$C_B$  = Backorder cost per unit per year (31:97).

The Stochastic EOQ Model. There are few cases where all assumptions of the previous deterministic EOQ models can be met. Demand and order and ship time (OST), in reality, are often stochastic not deterministic. The order and ship time may vary due to transportation or other order related problems, while demand may vary because of unforeseen requirements. These variabilities force organizations to build and maintain safety stocks (SS) to protect against stockout situations (15:20). The depth of these safety stocks is dependent upon several conditions:

1. Do stockouts result in lost sales?
2. How expensive are the holding costs for the item?
3. What is the variance in the order and ship time?
4. What is the variance in the lead-time demand?
5. What service level does the organization want to provide (31:184-189)?

If a stockout condition occurs before replenishment stock arrives, backorders will be filled prior to new customer demands when the stock does become available.

Demand and order and ship time variations are most frequently represented by the normal distribution. Figure 3 shows how a normal distribution applies to the stochastic EOQ model. The shaded area of the distribution,  $1 - F(x)$ , is the

cumulative probability of a stockout if lead-time demand is greater than the reorder point in terms of units. The probability of a stockout is:

$$F'(x) = 1 - F(x) = \frac{Q^* * C_H * C_U}{C_B * D} \quad (2.11)$$

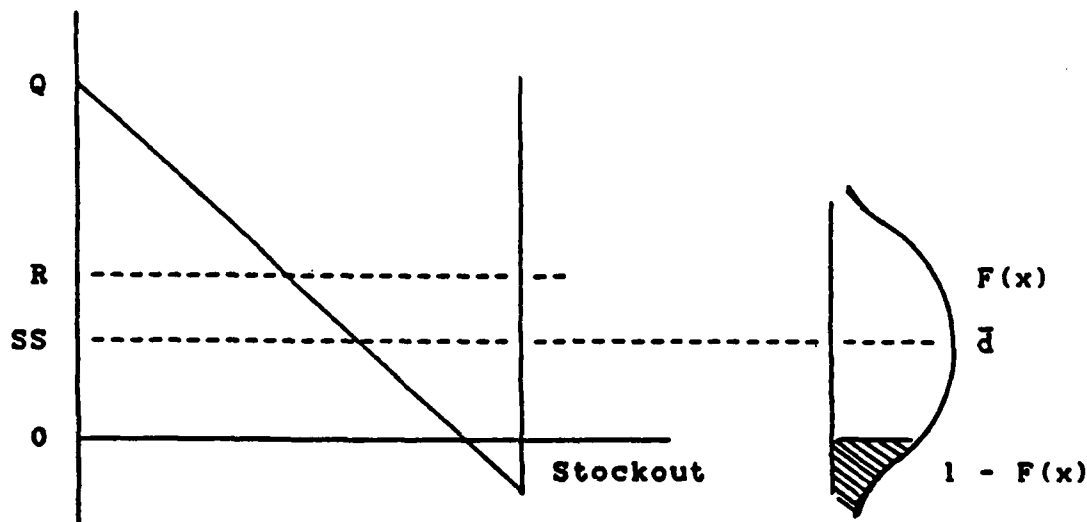


Figure 3. Stochastic EOQ Model (15:23)

With stochastic lead-time demand and order and ship time,  $Q^*$  is calculated using Eq (2.7). Given a stochastic leadtime demand and order and ship time, and assuming that both follow a normal distribution and are independent, then the combined mean ( $\bar{d}$ ) of the lead-times is:

$$\bar{d} = \mu_d * \mu_{OST} \quad (2.12)$$

and the combined variance of the lead-times is:

$$\sigma^2 = (\mu_{OST}) * (\sigma_d^2) + (\mu_d^2) * (\sigma_{OST}^2) \quad (2.13)$$

The combined standard deviation of the lead-times is then computed as:

$$\sigma = \sqrt{(\mu_{OST}) * (\sigma_d^2) + (\mu_d^2) * (\sigma_{OST}^2)} \quad (2.14)$$

where

$\mu_d$  = Mean of the lead-time demand

$\mu_{OST}$  = Mean of the order and ship time

$\sigma_d^2$  = Variance of the lead-time demand

$\sigma_{OST}^2$  = Variance of the order and ship time (15:25-26).

With these measures, the appropriate amount of safety stock to protect from the lead-time demand exceeding Z standard deviations is:

$$SS = \sigma * Z \quad (2.15)$$

The corresponding reorder point (R), for a given safety stock level of SS units, is:

$$R = \bar{d} + SS \quad (2.16)$$

The performance of the  $(Q^*, R)$  policy used may be measured the expected backorders per cycle (EBPC):

$$EBPC = \sigma * (E(Z)) \quad (2.17)$$

where  $E(Z)$  is the standardized stockout quantity for a standard normal distribution (31:219). An alternative performance measure to the EBPC is the fill rate (FR). The fill rate is a desired service level that an organization wants to provide its customers. It is the percent of customer demands filled from stock, and is calculated as:

$$FR = 1 - (EBPC / Q) \quad (2.18)$$

The stochastic EOQ model is the foundation for the Air Force Standard Base Supply System's expendable item model.

Standard Base Supply System. The Standard Base Supply System (SBSS) is an automated inventory accounting system designed to provide supply support to base-level activities. It is characterized as a multi-item, single-echelon, continuous review inventory system with stochastic, multiple unit demands, backordering and an annual budget constraint (22:1). Base Supply employs two versions of the classical EOQ inventory model formula (8:19-52). One version applies to local purchase items and the other is used for non-local purchase items. The objective of the Base Supply formulas are the same as for the classical EOQ model, to minimize the variable holding and ordering costs. The daily demand rate (DDR) used in supply calculations corresponds to  $\mu_d$  calculated for the stochastic model, while the variance of demand (VOD) and the variance OST (VOO) correspond to  $\sigma_d^2$  and  $\sigma_{OST}^2$  respectively. The EOQ formulas used in base supply

are based on a standard holding cost of 15 percent for both models. Standard order costs are also used in the formulas. For local purchase items a standard order cost of \$19.94 is used. With non-local purchases (from depot), a standard order cost of \$5.20 is used. When the standard order and holding costs are processed through the classical EOQ model (Eq (2.4)), they simplify to two different constant values. The values are a 16.3 constant for local purchase items and a constant of 8.3 for non-local purchase. Using these constant values, the resulting Base Supply formulas become:

$$\text{Local Purchase EOQ} = \frac{16.3 * \sqrt{\text{DDR} * 365 * C_U}}{C_U} \quad (2.19)$$

$$\text{Non-local Purchase EOQ} = \frac{8.3 * \sqrt{\text{DDR} * 365 * C_U}}{C_U} \quad (2.20)$$

The reorder level for EOQ items is computed by adding the order and shipping time (OST) quantity to the safety level quantity (SLQ) (Eq (2.16)) (8:19-30). In the supply system, the OST quantity (OSTQ) and SLQ are calculated as follows:

$$\text{OSTQ} = \text{DDR} * \text{OST} \quad (2.21)$$

$$\text{SLQ} = C * \sqrt{\text{OSTQ} * (\text{VOD}) + \text{DDR}^2 * (\text{VOO})} \quad (2.22)$$

where C equals the selected service level factor. In

practice, the C factor used in supply calculations is the same as the Z value (extracted from the normal distribution table) used when computing service levels with the classical EOQ formula. A C factor of one equates to an 84 percent service level, while a C factor of two equates to a service level of 97 percent (15:30).

The demand level for EOQ (EOQDL) items at base level is calculated by combining all of the factors affecting an item's availability. The formula for the EOQ demand level is:

$$\text{EOQDL} = \text{TRUNC} [\text{EOQ} + \text{OSTQ} + \text{SLQ} + 0.999] \quad (2.23)$$

The EOQ model is also used at the depot level. The safety level formula for depot stocks is, however, much more involved and complicated than with its base-level counterpart.

Economic Order Quantity at AFLC. The Air Force Logistics Command (AFLC) has a management objective to ensure maximum results in terms of supply availability and economy (1:12). To accomplish this objective, AFLC manages its assets through five Air Logistics Centers (ALCs) by using the D062 EOQ Buy Budget Computation System. The D062 system is a modified EOQ system which minimizes the variable costs of ordering, holding, and backorders. The model can be characterized as stochastic, multiple-item, single-echelon, with allowable backorders and required safety stock (15:31). The EOQ formula used by AFLC is listed in AFLCR 57-6 and is the same

classical EOQ version stated in Eq (2.4). The annual demand in the calculation is computed by using actual unit prices and the program monthly demand rate (PMDR) (1:81). The cost to hold inventory varies among the the ALCs (15:31).

The safety level (SL) for EOQ items is calculated as:

$$SL = K\theta \quad (2.24)$$

which corresponds to Eq (2.12), but is far more involved. The SL formula is a determination of how many (K) standard deviations' ( $\theta$ ) worth of demands to allow on a particular item (1:80);  $\theta$  is computed as (15:33):

$$\theta = (PPR)^{.85} (.5945) MAD (.82375 + .42625LT) \quad (2.25)$$

where

- PPR = Peacetime Program Ratio. A ratio used to calculate future inventory needs.
- MAD = Mean Absolute Deviation. The difference between a quarter's forecasted demand and the actual average (3 X monthly demand rate (MDR)).
- LT = Lead-Time. A function of PMDR, administrative, and production lead-times.
- .5945 = A constant which converts the mean absolute deviation from a quarterly to a monthly value.

.82375 = These are constants which express the variance and (MAD) over lead-time and recognizes that a .42625 particular month's demands are influenced by the previous months demands.

The standard deviation safety factor (K) is computed as (1:80,3:B-370):

$$K = -.707 \ln \left[ \frac{2 \sqrt{2} * C_H * Q * \sqrt{C_U}}{\lambda * \frac{1}{MIEC} * \theta * (1 - \exp(-\sqrt{2} Q/\theta))} \right] \quad (2.26)$$

where

MIEC = Mission Item Essentiality Code (A numerical value assigned to the item which shows how important the item is to the Air Force mission.)

$\theta$  = Standard Deviation of Lead-time demands

exp = Exponential Function

ln = Natural Logarithm

$\lambda$  = Implied Shortage Factor (A mathematical expression used to adjust the safety level in order to meet budget constraints for a specific time period (15:34)).

#### Repair Cycle Demand Level Model

Recall that reparable assets are defined as those spares that may be repaired or reconditioned and returned to a

serviceable condition for reuse (33:581). These spares (repair cycle assets) are managed in the Air Force through use of the Repair Cycle Demand Level (RCDL) inventory model (8:19-51 - 19-52). When an item fails during its operation, a maintenance technician will remove the failed part and request a replacement item from Base Supply. Once the issue of the item is made from Base Supply, the repair cycle time (RCT) for the spare begins (6:3).

Dependent upon the failed item's expendability, recoverability, repairability, category (ERRC) code, its technical order (T.O.) specifications, and the repair capability of the local base maintenance, a determination is made as to the level of repair that will be required to get the item back into the system, serviceable and ready for reuse. Repairable items may be repaired at the field (base) level (a single-echelon model) or at depot level (a multi-echelon model) (32:II-3-16). If the item is not repairable on base, it is turned-in to Base Supply as either not repairable this station (NRTS) (and shipped to the depot or a contractor maintenance facility for repair) or is condemned (and is sent to the base disposal office). The time to make this repair decision is the NRTS/condemned time (NCT). At the time of a NRTS turn-in, a requisition is forwarded to the supply depot responsible for the item in order to bring the base stock level back to equilibrium for the item (17:10). If the item is repairable on base, it is forwarded to the applicable

maintenance organization for repair. The fraction of items repaired on base is the percent of base repair (PBR). Once repaired, the item is turned-in to Base Supply and becomes a part of the base stock replacing the previously issued item (10:9). When this turn-in to Base Supply is accomplished (whether repaired or NRTS), the RCT ends.

The Repair Cycle Demand Level (RCDL) model follows an (S-1, S) inventory policy. In this (S-1, S) inventory system, a one-for-one ordering policy is followed (12:1). In the RCDL model, S is the stock level authorized a base to support customer organizations, while S-1 is the reorder point for the item. The stock levels are calculated based on the average time that an asset can spend in the repair and depot-to-base replenishment cycles, with an additional safety quantity for stockout protection (5:1). The quantity of a reparable item that a base will stock, S, is given by the following formula (6:8):

$$S = RCQ + OSTQ + NCQ + SLQ + K \quad (2.27)$$

where

RCQ = repair cycle quantity.

OSTQ = order and ship time quantity.

NCQ = NRTS/ condemned quantity

SLQ = safety level quantity.

K = constant,

.5 if the unit cost is greater than \$750, or

.9 if the unit cost is \$750 or less (8:19-51).

Further, each of the above quantities are calculated as follows:

$$RCQ = DDR * PBR * RCT \quad (2.28)$$

$$OSTQ = DDR * (1-PBR) * OST \quad (2.29)$$

$$NCQ = DDR * (1-PBR) * NCT \quad (2.30)$$

$$SLQ = C * \sqrt{3 * (RCQ + OSTQ + NCQ)} \quad (2.31)$$

where

$$DDR = \frac{\text{Cumulative recurring demands}}{\text{Max (180, current date - DOFD)}}$$

$$PBR = \frac{\text{Number of repaired units} * 100}{\text{Sum of units repaired, NRTS, condemned}}$$

$$RCT = \frac{\text{Sum of repair days}}{\text{Number of units repaired}}$$

$$NCT = \frac{\text{Sum of NRTS/ condemned days}}{\text{Number of units NRTS/ condemned}}$$

$$\text{OST} = \frac{\text{Sum of depot-base ship days}}{\text{Number of units received}}$$

C = C-Factor. The number of standard deviations used to protect against stockouts (8:19-51).

DOFD = Date of first demand.

### Backorder-Centered Models for Recoverable Assets

Overview. These recoverable asset models are designed for multi-item environments. This differentiates them from the Repair Cycle Demand Level (RCDL) model which is used in setting stockage policy for a single-item environment. Also, backorder-centered models use constrained optimization techniques to set stockage policy. All of the backorder-centered models presented in this study have some similar characteristics.

The first characteristic is that all of these models use Palm's theorem. This theorem states: if demands arrive (at a service queue) according to a Poisson process, then the number of items in resupply is also Poisson for any arbitrary distribution of demands (7:5). Secondly, all of these backorder-centered models use expected backorders as a performance measure. The third characteristic is that each of these models represents a steady-state situation. This means that the demand rate remains constant over time. This constant demand rate makes these models more appropriate for peacetime rather than wartime use (15:43). The two types of

backorder-centered models included in this study are the METRIC and MOD-METRIC models.

The METRIC Model. The Multi-Echelon Technique for Recoverable Item Control (METRIC) model has three purposes. The model's main purpose is to determine base and depot stock levels. Another purpose is to determine the stock levels that would minimize expected base backorders. The third purpose of the model is for analysis of inventory system performance (19:1-2).

The METRIC model makes the following assumptions (27:129-130):

1. The demand distribution is stationary.
2. No lateral resupply between bases.
3. No condemnations are allowed.
4. Base and depot repair begins immediately when a broken recoverable item arrives at the shop or depot.
5. Items are considered equally essential.
6. Demand data from different bases can be pooled to create one estimator of a demand rate.

The system objective of the METRIC model is to minimize the expected number of backorders for all recoverable items belonging to a specific weapon system (27:126). The number of units in the repair pipeline is (15:52):

$$\lambda_{ij} T_{ij} = \text{DDR}_{ij} [(\text{PBR}_{ij} * \text{RCT}_{ij}) + \text{NRTS}_{ij} (\text{OST}_{ij} * \text{DDT}_i)] \quad (2.32)$$

where

$\lambda_{ij}$  = DDR (The daily demand rate for an item  $i$   
at base  $j$ )

$T_{ij}$  = Number of item  $i$  in maintenance at base  $j$   
after failure

$DDT_i$  = Depot Delay Time for item  $i$  (To account for delays  
due to depot stock shortages or asset repair).

The expected number of units delayed at the depot for  
some arbitrary point in time is (19:5):

$$B(S_0; \lambda D) = \sum_{X=S_0+1}^{\infty} (X - S_0) p(X; \lambda D) \quad (2.33)$$

where

$S_0$  = Depot stock

$X$  = Number of demands

$D$  = Average depot repair time

$\lambda = \sum (\lambda_j (NRTS_j))$ , given  $\lambda_j$  is the monthly demand rate  
at base  $j$  and  $NRTS_j$  is the percentage of units NRTS  
at base  $j$ .

If  $B(S; \lambda D)$  is divided by  $\lambda$ , the result is the expected  
depot delay time for item  $i$  (27:133):

$$DDT_i = \frac{B(X; \lambda D)}{\lambda} \quad (2.34)$$

Considering that the objective of the model is to minimize expected backorders (given a fixed depot stock level) subject to a budget constraint, the METRIC model can be described mathematically as:

$$\text{Minimize: } \sum_{i=1}^n \sum_{j=1}^m E(B_{ij} | S_{ij}) \quad (2.35)$$

Subject to:

$$\sum_{i=1}^n C_i (S_{i0} + \sum_{j=1}^m S_{ij}) \leq \text{budget constraint} \quad (2.36)$$

where

$i$  = Item (n different items)

$j$  = Bases (m different bases)

$C_i$  = Cost of an item  $i$

$S_{ij}$  = Stock level item  $i$  at base  $j$

$S_{i0}$  = Depot stock levels of item  $i$ .

The MOD-METRIC Model. The MOD-METRIC model is a modification of the METRIC model. It introduces a hierarchical relationship in a weapon system's parts structure. The more expensive components of weapon systems, known as Line Replacement Units (LRUs), are made up of subcomponents called Shop Replacement Units (SRUs). When an aircraft has a defective LRU, a maintenance technician

removes the defective LRU and it is taken to the shop for repair. In the shop the defective SRU is removed from the LRU and is replaced with a serviceable SRU that has been ordered from supply. The following assumptions apply to the MOD-METRIC model:

1. All METRIC assumptions except that now all items are not considered equally essential.
2. Each LRU failure is due to only one SRU failure.
3. Each SRU belongs to only one LRU.
4. LRUs are normally repaired at base-level while SRUs are repaired at the depot (15:58).

The objective of the MOD-METRIC model is to minimize expected backorders for all end-items subject to a dollar constraint on the inventory investment in both LRUs and SRUs. MOD-METRIC computes the average number of LRUs in resupply as (20:476):

$$\begin{aligned} \lambda_{ij} T_{ij} = & \text{DDR}_{ij} [\text{PBR}_{ij} (\text{RCT}_{ij} + \text{SDT}_{ij}) \\ & + \text{NRTS}_{ij} (\text{OST}_{ij} + \text{DDT}_i)] \end{aligned} \quad (2.37)$$

where

$\text{SDT}_{ij}$  = The average delay in base j's repair of LRU i due to the unavailability of an SRU.

Mathematically, the MOD-METRIC formula to derive the stock level becomes:

$$\text{Minimize: } \sum_{j=1}^m \sum_{i=1}^n \sum_{X_i=S_i+1}^{\infty} (X_i - S_i) p(X_i | T_i) \quad (2.38)$$

Subject to:

$$\sum_{j=1}^m \left[ C_e S_j + \sum_{i=1}^n C_i S_{ij} \right] + \sum_{i=1}^n C_i S_{0i} + C_e S_0 \leq \$ \text{ constraint} \quad (2.39)$$

where

$S_j$  = Stock level of spare LRUs at base  $j$

$S_{ij}$  = Stock level of spare SRU  $i$  at base  $j$

$C_e$  = Unit cost of an LRU

$C_i$  = Unit cost of SRU  $i$ .

The importance of backorder-centered models is twofold. First, they formed an important part in the evolution of repairable inventory models. Secondly, the USAF D041 Recoverable Items Consumption System uses METRIC/MOD-METRIC logic in allocating repairable spares to Air Force bases. The next set of models shift their focus to aircraft availability.

#### Availability-Centered Models for Recoverable Assets

Overview. Availability-centered models use operational aircraft availability as a performance measure. The two primary performance measures used are Not Mission Capable Supply (NMCS) aircraft and Fully Mission Capable (FMC)

aircraft. These measures provide information on the availability of the aircraft fleet, given a stock level and a demand rate (15:62). Two models are addressed in this section. They are the Logistics Management Institute (LMI) availability-centered model and the Dyna-METRIC model.

LMI Availability-Centered Model. The LMI availability-centered model converts expected backorders (and expected backorder reductions) into expected NMCS aircraft (and expected NMCS reductions). It can predict an expected number of NMCS aircraft given that an initial number of recoverable spares exists for each recoverable component (9:11-12).

The assumptions of the LMI model are (9:12):

1. An aircraft missing a recoverable component due to a stockout condition will be NMCS if the component would cause an NMCS condition.
2. An aircraft cannot be NMCS unless at least one unit of a NMCS-causing component is in need of repair and a spare is not available.
3. The failure of any single NMCS-causing component is independent of the failure of any other component, and is independent of the operational state of the aircraft on which it is installed.
4. When more than one unit of any component is installed on an aircraft, the failure of one unit is independent of the failures of any of the other units.

The objective of the LMI model is to minimize the number of NMCS aircraft given a constraining budget value. The probability that an aircraft is not missing an item (i) is given by the equation (15:64):

$$1 - \frac{E(B_i)}{F} \quad (2.40)$$

where

$E(B_i)$  = Expected number of backorders for item i.

F = Fleet size.

If the quantity per aircraft for a particular item ( $QPA_i$ ) is greater than one, then the equation becomes:

$$1 - \left[ \frac{E(B_i)}{F * QPA_i} \right]^{QPA_i} \quad (2.41)$$

The probability that an aircraft is not missing any items (it's available) is the product sum of all the probabilities of that aircraft not missing item (i) (9:52).

LMI also allows for a cannibalization policy. This has the net effect of increasing the FMC rate because a number of aircraft can now be used as a source of supply for parts. With full cannibalization, the operational rate can be defined as a function of the number of aircraft (M) used as a supply source (cannibalization). With the effects of cannibalization considered, the probability for the expected number of NMCS aircraft is (15:67):

$$\text{Expected NMCS} = \sum_{M=0}^F \left[ 1 - \left( \prod_{i=1}^n \left( \sum_{x=0}^{S_i + (M \cdot QPA_i)} p(X; \lambda_i T_i) \right) \right) \right] \quad (2.42)$$

These measures of aircraft availability provided an important step in reparable inventory model evolution. They are the fundamental performance measures for Dyna-METRIC.

Dyna-METRIC Model. The Dyna-METRIC model uses aircraft availability or operational criteria performance measures. It is a multi-echelon, multi-indenture, multi-item, multi-location, stochastic model. It is important to note that Dyna-METRIC sets stockage policy in a dynamic demand environment. That is, it allows a manager to look at wartime scenarios and determine the effects of inadequate logistical support. In doing so, the manager can predict aircraft readiness given a level of logistics resources (24:1-2).

The limitations of the Dyna-METRIC model are (16:10-13):

1. Repair procedures and productivity are unconstrained when computing pipeline probability distributions.
2. Dyna-METRIC does not directly assess the effects of lateral supply across bases.
3. Aircraft at each base are assumed to be nearly interchangeable.
4. Constrained repair computations only approximate probable logistics system performance.

5. Dyna-METRIC's computations are only precise with order quantities of one. As order quantities increase (as is with EOQ items), pipeline variability also increases.
6. Dyna-METRIC does not compute the joint probabilistic effects of backorders and AWP quantities with related pipelines.
7. The effects that flight line resources and operational constraints have on sortie rates must be estimated by other models or analysis and then incorporated into Dyna-METRIC's sortie rate parameter.

The Dyna-METRIC model also considers the impact of SRUs (subcomponents) on LRUs. Its primary objective is to avoid a degradation of aircraft mission capability due to a shortage of recoverable components. To accomplish this goal, the supply of these components needs to exceed the number of components tied up in the repair and resupply pipelines (14:3). The Dyna-METRIC model computes the expected pipeline quantities for each LRU, SRU, and sub-SRU at the base, Centralized Intermediate Repair Facility (CIRF), and depot levels. The model uses a building block approach to determine the LRU pipeline requirement. It considers that demands for sub-SRU components have an affect on SRU requirements and that SRU demands in-turn affect LRU requirements.

The input data is categorized into four data sets in the Dyna-METRIC model. The first of these data sets is the administrative data. These inputs include a specification of the run's heading, any administrative delays for reparable processing, and the time periods used for analysis. Also entered in the administrative data set are the user selected output options. The user indicates the output "options" which will provide the computations or reports the user needs for analysis.

The second input data set contains location descriptions. The only mandatory input in this area is a description of the base under evaluation. For example, a squadron may deploy to a location (base) specified by input as LOC1. All further model inputs that would involve the base (its assigned number of aircraft or its repair relationship with an intermediate repair facility) will be tied to this base designator. There are three optional inputs that may be entered to broaden the scenario; a description of: 1) the depots involved, 2) the intermediate repair facilities (CIRFs) that may be used, and 3) a description of the depot transportation available.

The third set of data inputs are the scenario data. There are three mandatory input items in this set. They include the number of aircraft to be used in the scenario, the sortie rates required of the aircraft, and the maximum sortie rates. The optional inputs to this set are the

aircraft attrition rates, flying hours per sortie, the maintenance types, and the mission requirements.

The last set of data required is the component data. The mandatory input is a description of the LRUs used in the scenario. Their current or proposed stock levels may be input if an assessment of stock level adequacy is desired. The optional inputs for this data set include a description of any SRUs and subSRUs used in the scenario. The indenture relationships of the SRUs/subSRUs used must also be input if SRUs and subSRUs are listed. The quantity per aircraft and any other optional LRU data is entered in this data area too (16:140).

As a result of the data input, and based on the output data requested, a series of reports are created. These reports provide measurement data upon which the modeled logistic system can be evaluated. It also provides diagnostic information to judge the scenario's logistic performance and/or a listing of the spares requirements needed to fulfill a desired mission. Also, to ensure the accuracy of input data, these echo reports may be requested:

1. Overall Information and Indenture Relationships
2. Base, CIRF, and Depot Related LRU, SRU, and SubSRU Data
3. Specific LRU Information
4. Quantities Per Aircraft
5. Initial Stock Levels.

Examples of the output that may be printed from an input scenario include (16:18-77):

1. Performance Based on Stock on Hand on Day XX
2. World-Wide Component Support Impact - Day XX
3. Detailed Pipeline Segment Report For Problem LRUs, SRUs, SubSRUs
4. Potential Problem Parts Report
5. Detailed Pipeline Segment Report For Problem LRUs, SRUs, SubSRUs
6. Detailed Pipeline Segment Report at Depot XXXX on Day XX
7. Detailed Pipeline Segment Report at Base XXX on Day XX
8. Detailed Demand Rate Report
9. Depot Workload Report.

Other reports are also available. As can be seen by the above list, Dyna-METRIC provides a wealth of output data upon which to judge different wartime scenarios.

The next section moves from the independent demand environment to one of dependent demand. With dependent demand, supply requirements are based on a planned level of output. One method the Air Force is experimenting with to control a dependent demand environment is called Material Requirements Planning (MRP).

## Material Requirements Planning

Material Requirements planning (MRP) is a computer-based production and inventory-control system designed to improve a plant's operating efficiency (13:532). To accomplish this, MRP attempts to:

1. Ensure materials and components are available for planned production and for customer delivery,
2. Maintain the lowest possible inventory, and
3. Plan manufacturing activities, delivery schedules, and purchasing activities (31:328).

MRP has three major inputs that provide it with data. The first of these is the master production schedule (MPS). The MPS indicates what products are needed and when they are required. The second input to MRP comes from product structure records, also known as the bill of materials (BOM) records. These show how a product is produced and what quantities of components will be required to build the end-item. The third input is the inventory status records. These contain the on-hand balances, open orders, lot size requirements, lead-times, and safety stocks for each inventory item. MRP takes the data from the three inputs and issues reports on (31:331):

1. What items need to be ordered and how many,
2. When to submit the orders,
3. What orders to expedite and which ones to deexpedite or cancel.

After accumulating and processing the inputs, MRP issues planned order releases detailing the production plan necessary to complete the end-item order requirements.

Manufacturing Resource Planning (MRP II). The version of MRP being used by the Air Force Logistics Command is known as Manufacturing Resource Planning (MRP II). The Ogden Air Logistics Center at Hill AFB, Utah, is using MRP II in an effort to reduce repair times on aircraft and missile recoverable assets and end-items. MRP II is an MRP package of computer modules that allows a firm to evaluate and manage different resource (labor, output capacity, etc.) plans. The benefits MRP II may provide are (30:457-458):

1. Inventory reductions
2. A higher inventory turnover ratio
3. Improved customer delivery times
4. Minimize worker overtime.

Figure 4 is an illustration of a typical MRP II system. This figure displays the various informational inputs, planning levels, and logic used by the system. It also shows how the organization as a whole is tied together in the system.

### Summary

This concludes the literature review. It began with a discussion of inventory theory and progressed to the first set of inventory models used by the Air Force, the EOQ models. It then moved on to an examination of repairable



asset inventory models. The first of these was the Repair Cycle Demand Level model. Next, the backorder-centered models were covered. These included the METRIC and MOD-METRIC models. The next section covered availability-centered models. The two discussed were the LMI availability-centered performance measures and the Dyna-METRIC model. Finally, the last section dealt with the Material Requirements Planning (MRP) inventory control system. In particular the MRP II version was covered.

The models presented in this literature review were selected to provide background information for the models to be used as case studies in Chapter IV. These models represent the methods used by the Air Force to control its expendable and reparable assets. A better understanding of these models and their components will enable Air Force supply personnel to enhance the model's potential.

Chapter III contains a description of the methods to be employed in collecting data for this study. This collected data will be used in the models presented in Chapter IV's case studies. Chapter III also contains a discussion of why case studies were chosen as the best method to explain to Air Force supply personnel how the selected inventory models and their components work.

### III. Methodology

#### Chapter Overview

This chapter describes the methods that will be employed in the research. The first section covers the data collection methods. It includes a description and justification for the use of observation and personal interviews as the data collection means. The second section lists the data collection plan. It covers the various actions that are required to collect the data. The third section discusses the method employed in analyzing and reporting the collected data. It includes a discussion on why case studies are considered the best method to reinforce the concepts and to describe the techniques of the inventory models covered in the study.

#### Data Collection

With the exception of the Manufacturing Resource Planning (MRP II) model, information exists and is available at Wright-Patterson AFB, Ohio to complete the research required for this thesis. The data collection methods are observation and personal interviews.

Observation is the primary collection method. It has a number of very important advantages for this study. First, most of the data assembled for the study comes from existing records and reports. The variety of organizations located at Wright-Patterson AFB allowed the study to cover models from

the standpoint of both command and base levels without lengthy travel. The second advantage is that the observation method allows for collecting data as it occurs. This permits collecting more complete data about the actual events that occur as supply items are evaluated by the various inventory models. The third important advantage of the observation method is that one can see the effects on original data as it is manipulated by the inventory models.

The primary disadvantages associated with the observation method are: 1) the time required for its use, and 2) the amount of observer involvement. For this study, these disadvantages had minimal impact. The observation method is normally considered a slow, time consuming process as the observer waits for events to happen (11:158). The close proximity and accessibility of the data sources for this study meant that travel time was minimal. Also, the majority of the data collected resulted from events that occur on a regular basis at the command and base level. The remaining data came from existing reports and listings or from expert sources available at Wright-Patterson AFB.

The second data-collection method employed in this study was personal interviewing. This method was used to obtain information to provide additional depth and detail about the data collected by observation. Prior to an interview, the collected data was examined for discrepancies and model fit. From this examination, a list of questions was developed to

guide the interview. These questions were tailored to the specific unit from which the observed data was collected and used to clarify the data collected or to help explain any extraordinary circumstances affecting the data or its collection.

The personal interviewing method was the primary data source for information concerning the Air Force's use of a Material Requirements Planning (MRP) model. MRP is an inventory model being implemented at Ogden Air Logistics Center (ALC), Hill AFB, Utah. The version of MRP being used is known as Manufacturing Resource Planning (MRP II), and is used to plan and track depot-level maintenance actions. There are representatives at Wright-Patterson AFB who are responsible for monitoring this new program. These individuals, and other AFLC experts, provided the required background and data for studying the MRP II model.

This combination of methods, observation and personal interviewing, provided actual data from on-line Air Force supply inventory models. These methods gave the best possible authenticity to the workings of the various Air Force models presented in this study.

#### Data Collection Plan

The following activities were required to collect data for the study:

1. For base-level inventory models:
  - a. Observe and record the movement of reparable assets through the Standard Base Supply System (SBSS).
  - b. Observe and record the results of requirements computation on preselected Base Supply items.  
(See note 1 for the item preselection criteria.)
  - c. Observe and record the effects of Not Reparable This Station (NRTS) and reparable item condemnations on the repair cycle system.
  - d. Observe and record the effects of item request backorders on supply system effectiveness.
  - e. Observe and record how the EOQ formula is applied at the base level.
2. For AFLC level inventory models:
  - a. Observe and record the status records of various preselected reparable and expendable supply items.  
(See note 1 for the item preselection criteria.)
  - b. Observe and record changes in the D062 EOQ Buy System for the preselected items.
3. For the Manufacturing Resources Planning model:
  - a. Contact the AFLC MRP II representative for a briefing on its objectives and scope.

- b. Contact Hill AFB for a status briefing on its progress and acceptance.

Note 1: The preselection of supply stock numbers used in this study will be based on a review of supply/depot reports and listings. Items that have a demonstrated high demand rate and a consistent transaction history will be considered for use since they provide the best examples of inventory model application.

#### Reporting Method

After examining the various inventory models in the literature review, and collecting the data, each model is presented to best demonstrate its concepts and techniques. The best means for this is through developing case studies, since they emphasize the entire situation or sequence of events surrounding a situation (26:172). There are a number of advantages to the use of case studies. First, they can demonstrate the full complexity of the model being presented. This is an important point since all the components can be presented and their relationships within the model established. A second important reason is that case studies are useful vehicles for providing insights into how the model and its components work (29:137-138). Since the case studies use common Air Force supply settings, they provide for a more relevant learning experience.

An individual case study presentation is developed for each model. These presentations are representative of

everyday activities at the Base Supply or depot where the models are used. Each presentation includes:

1. A situation which requires the model's usage.
2. The data required for the model's variables.
3. Example calculations/applications of the model to the data.

The goal of these presentations is a better understanding of the models themselves. Following each presentation are a series of questions which either requires manipulation of some data provided or provides topics for discussion. The answers to these question are designed to provide insight into the model's operation.

#### Summary

This chapter discussed the methodologies used in the research effort. It covered the methods to be used in data collection (observation and personal interview), and the method to be used in reporting the results (case studies). The case studies are presented in Chapter IV.

#### IV. Case Studies

##### Case Number 1: Base Level EOQ Model

Overview. The following scenario involves a Base Supply squadron. It demonstrates how the Economic Order Quantity (EOQ) inventory model is used at base level. The scenario shows how the EOQ value can be computed for both local and non-local purchase requests. Also computed in the scenario are the safety level quantity, the reorder level, and the EOQ demand level (EOQDL).

Situation. In an attempt to reduce depot inventory costs, Air Force Logistics Command (AFLC) is allowing some bases to buy high-use, expendable items through local purchase. For a base to qualify they must submit proof that the additional cost of this purchasing method is less than 15 percent greater than would be experienced through requisitioning the item from a depot. The 15 percent figure was the average amount per item that AFLC felt it could save on its own handling and transportation costs if it could stock and ship less of an item.

To determine candidate items that could be used to test this offer, the local Base Supply squadron ran an inquiry of all the stock numbers loaded in their computer inventory system. The elements they were looking for on the inquiries were the item's routing identifier code (RID), its date of last transaction (DOLT), and its current demand level. The

reason for their interest in the RID is that only AFLC depots are permitting the local purchase option. The next item, DOLT, gives the squadron an idea of how recently some sort of transaction (for example an issue) was recorded on the item's internal computer record. Items that have a DOLT exceeding 45 days are to be excluded from the test. A secondary purpose of this test, besides reducing depot inventories, is to allow bases to establish local supply sources and reduce their needs for additional (safety) stock to cover depot lead-time demands. Lastly, the Supply Squadron will be interested in the current demand level. This will give the squadron an idea of how frequently the item is requested.

Model Input Data. The inquiry that the Supply Squadron processed yielded many possible candidates for the program. One of those items is shown in Table I.

Table I

Base Level EOQ Model Input Data

Stock Number:	5305001775542	Inquiry Date:	8132
Nomenclature:	Bolt, Lag, 3 In. Lg.		
Demand Level:	70		
Routing Identifier Code:	FPZ		
Serviceable Balance:	0		
Unit of Issue:	HP		
Date of Last Transaction:	8126		
Item Cost:	\$2.40		
C Factor:	1		

An informal sampling of local hardware suppliers was conducted by the Base Procurement office for this item. This survey revealed that the unit cost (unit of issue = 100) would be \$2.75 if purchased locally (for lots of 100) and that there were multiple sources available. Each of these sources reported that they maintained a consistent on-hand balance for the item.

For depot requisitions, it was discovered that the average order and ship time for the item was 30 days. It was also determined that the amount of stock required to cover the variance for the order and ship time was 20 units. The variance of demand for the item was found to be 12 units.

Case Questions.

1. Using the base-level EOQ formulas [Eqs (2.19) and (2.20)], what are the local purchase and non-local purchase EOQ values.
2. If the base requisitions the lag bolt from the depot, what are the SLQ, reorder level, and EOQDL values?
3. What do you think of the AFLC policy of letting bases purchase "fast movers" locally?

## Case Number 2: AFLC EOQ Model

Overview. EOQ items are nonrecoverable (consumable) assets which have an expendability, recoverability, repairability code (ERRC) of XB3 or XF3. Under a selective management program, the EOQ Buy Budget Computation System (D062), EOQ items are categorized based on the dollar value of their projected annual demands and the frequency of their demands. The categories these items are assigned are known as Supply Management Grouping Codes (SMGCs). The SMGC assignments are determined by the D062 system and they denote the degree of management intensity required. For all items, AFLC's the management objective is to ensure the maximum results in terms of supply availability and economy (1:12).

The depot's stock level requirement, for consumables, is calculated in part by the AFLC Retail Stock Control and Distribution System (D033). The D033 computes the depot's stock level (safety level plus order and ship time plus EOQ operating stock) which supports all users (base and depot-level) of the item. To complete the stock level requirement, the War Reserve Material (WRM) authorizations and any project authorizations are added to the stock level. The D062 then computes the depot supply level as the sum of the back order quantities (user requirements) plus the depot stock level requirement. (1:19). In the following scenario only the D033 EOQ and safety level quantity computations are addressed.

Situation. Recently, there has been an increase in the number of customer complaints received at Headquarters AFLC. The complaints center around what appears to be an increasing number of the customer's requisitions being backordered. In response to this, the AFLC Commander has tasked his Materiel Management Branch (AFLC/MMM) to investigate the situation. They are to investigate the complaints and determine if the problem stems from: 1) increased demands, 2) increased contractor difficulties, 3) a problem with the computer program used to calculate AFLC safety stock levels, or 4) some other cause.

Three separate working groups were established to research the most likely problem areas identified. The group looking at item safety levels decided that the best way to evaluate the computer's accuracy was to manually compute safety levels for a sample of items and then compare these values with the items' computer generated safety levels. These manual computations were accomplished using the AFLCR 57-6 (Requirements Procedures For Economic Order Quantity (EOQ) Items) formulas. There was little doubt that the computer program was functioning properly, but this comparison would ensure that it was receiving all the data needed to comply with the AFLCR 57-6 requirements. Also, by computing the safety level values manually and comparing them with the computer generated ones, the group would have

definite proof that the computer program was operating properly.

Model Input Data. The system inquiry processed on the first item contained the information shown in Table II.

Table II

AFLC EOQ Model Input Data

Stock Number: 1650000914319  
Nomenclature: Plate, Oil Seal  
Cost: \$11.70  
Unit of Issue: EA  
Supply Management Grouping Code: T  
EOQ Year Factor: 3.0  
Peacetime Program Ratio: 1.038  
Administrative Lead-time: 4.24  
Production Lead-time: 7.23  
Program Monthly Demand Rate: 3.83  
Implied Shortage Factor: 45  
Mean Absolute Deviation: 10.38  
Mission Item Essentiality Code: 2AE  
Safety Level: 28  
EOQ Value: 138

To compute the safety level, one must first compute the standard deviation of demand ( $\theta$ ) and the standard deviation safety factor ( $K$ ). All the data elements necessary to compute  $\theta$  are given in the inquiry, except for the lead-time

(LT). In accordance with AFLCR 57-6, this is defined as the administrative lead-time (ALT) plus the production lead-time (PLT). After computing  $\Theta$ , K can be calculated. In computing K, all the required data is present in the inquiry except for two parts. The first is the holding cost. This is dependent upon the AFLC depot to which the item is assigned. For Oklahoma City, which manages this item, the holding cost is 10 percent. The second part missing is the numeric value of the mission item essentiality code (MIEC). The inquiry lists the MIEC as 2AE. The reason that it is maintained internally as 2AE is to provide a means of determining how important this item is to the Air Force mission. The first position of the MIEC tells what kind of system the item is used on (2 = strategic), while the second and third positions reflect the item's impact on the system (A = lack of the item would cause a Not Mission Capable condition, E = item is critical for operation). The computer automatically converts this code to its corresponding numeric value. Manually, the value assigned to an item with a MIEC of 2AE is 4. The lower the MIEC value, the more important the item is. With these two pieces of information, the previously computed  $\Theta$  value, and the data listed on the inquiry, one can now compute K.

#### Case Questions.

1. What is the standard deviation of the lead-time demands ( $\Theta$ ) for the data presented?

2. How many standard deviations (K) should be used to calculate the item's safety level?
3. What is the safety level for this item?
4. What should be the computed depot stock level for this item (assume  $OST = ALT + PLT$  or 11 units) ?

### Case Number 3: Repair Cycle Model

Overview. This section covers an example of the Repair Cycle Demand Level (RCDL) model. The RCDL model calculates the spare stocks (repair cycle demand levels) necessary for each individual base, considering that base's repair capabilities and consumption patterns. The model considers the amount of stock necessary to fill the on-base repair cycle and depot-to-base replenishment pipelines as well as a safety factor quantity to cover demand variability. The RCDL model follows an S-1,S inventory policy and is used only for reparable items. A description of the S-1,S inventory policy is given in Chapter II. Under this policy, customers are limited to ordering one unit per request. This limitation allows greater control of each item in the repair and replenishment pipelines.

Situation. Under the new Federal Base Closure Act, the Air Force has decided to consolidate several of its smaller bases with some of its larger ones. The aircraft squadrons assigned to these smaller bases will be moved to other wings possessing identical or similar aircraft fleets. However, for one of the closing bases, Clover Field AFB, MT, the desired matching is not going to be possible. Its Squadron, the 49th FIS, is comprised of F-106A and B aircraft, models not used anywhere else in the active Air Force inventory. The 49th FIS, along with its trained maintenance personnel will be assigned to Minot AFB, ND, where the 5th FIS operates

F-16s in the air defense role. The movement of the already trained maintenance personnel (49th AMU) will ease the squadron's transition into its new base environs, but the differences in aircraft models will pose some problem with early supply support.

Model Input Data. To make the transition as smooth and effective as possible, the 49th AMU and the gaining 321st Supply Squadron, have been discussing the supply support that will be necessary. The Maintenance unit reviewed their records for each of the aircraft being reassigned to the new base. The purpose of this review was to establish a demand history for the various repair cycle items the Squadron would need. The Maintenance units, at both Clover Field and Minot AFBs, also provided estimates on their repair capabilities to the 321st Supply.

After collecting all the data, the Supply Squadron assembled preliminary repair cycle records for the new (F-106 unique) repair cycle items. Supply gathered this data to determine what initial spare stocks they should add to provide effective support to the new unit. The following table contains an example of the data collected on each repair cycle item.

Table III

Repair Cycle Model Input Data

Number of units repaired:	12
Repair cycle - in days:	30
Number units NRTS/condemned:	4
NRTS/condemned days:	5
Order and ship time - in days:	20
Unit price - in dollars:	1400
Daily demand rate:	.0328

In computing the anticipated repair cycle demand levels, the Supply Squadron used a C factor of one in its calculations.

Case Questions.

1. What is the percentage of base repair (PBR), given the available data?
2. What is the order and ship time quantity (O&STQ), using the PBR calculated in question 1?
3. What is the repair cycle quantity (RCQ) for this data?
4. What is the NRTS/condemned quantity for this problem?
5. Using the above calculated values, what is safety level quantity (SLQ) required of this data?
6. What is the anticipated stock level (S) that will be required to support this base's needs?

Note: AFM 67-1, Volume II, Part 2 describes the Air Force procedures to be used in providing supply support during weapon-system transfers (New Activation Spares Support List-NASSL). A May 1988 Air Force Logistics Management Center study reveals, however, that gaining units often supplement the NASSL process with "ad hoc methods" (25:abstract).

Although the scenario in this case is not unrealistic, its intent was solely to familiarize the reader with the RCDL model.

#### Case Number 4: METRIC Model

Overview. The Multi-Echelon Technique for Recoverable Item Control (METRIC) is a mathematical model used to determine base and depot stock levels for reparable items. It accomplishes this goal by optimizing system performance, given a specified investment constraint or system performance criteria. This system optimization involves allocating the available reparable inventory for a weapon system between the bases (users) and the depot such that the sum of the expected backorders for the required items will be minimized. The METRIC model can also be used for analysis of inventory system performance.

Situation. In an effort to modernize and improve its post-strike assessment capabilities, the Air Force has decided to fund and test a new flight mission recorder set. This new system will use the latest in high resolution VHS video technology. The set consists of two main components, a recording unit and an imaging unit. Both of these components are reparable items.

The testing of the new mission recorder sets will be accomplished at two bases. Each base supports the same type of aircraft, but each has a slightly different maintenance capability. The Air Force has set the length of the test at two years. During that period the Air Force will study the reliability of the new system, examine each of the test base's ability to repair and maintain the system's

components, and determine the depot supply support that will be required if the item is adopted for Air Force-wide use.

Model Input Data. Buying the new mission recorder sets will be accomplished with two separate budget requests. The initial buy will be for the base replacement units. These will be used to change-out the currently installed systems. The second buy will be for the required support stock. The stock from this buy will be used to provide for the system's initial supply support. METRIC will be used to allocate the spare assets between the test bases and the supporting depot. Minimizing item backorders is the supply system performance measure of choice. The initial data used in the METRIC model computations are listed in Table IV. This data reflects the anticipated daily demand rate for the two components, the percentage of base repair expected for each of the bases, and the estimated repair cycle times. Also included are the order and ship times for the items, their cost (all cost figures in this table and throughout the remainder of this case are X \$10,000.), as well as the expected depot delay time.

The last of the model input data are the budget constraint and the depot stockage requirements. The budget limit for the spares stock buy was set at \$39. Initially, the depot decided to stock two of each component. The cost for depot stock is then \$14. This means that \$25 is left to purchase spares for the test bases.

Table IV

METRIC Model Input Data

Recorder Unit:	<u>Base 1</u>	<u>Base 2</u>
DDR =	.4	.4
PBR =	1.0	.9
RCT =	5.0	5.0
OST =	20.0	20.0
DDT =	10.0	10.0
Cost =	3.0	3.0

Imaging Unit:	<u>Base 1</u>	<u>Base 2</u>
DDR =	.4	.4
PBR =	.8	.9
RCT =	5.0	5.0
OST =	20.0	20.0
DDT =	10.0	10.0
Cost =	4.0	4.0

Case Questions.

1. What is the pipeline value ( $\lambda T$ ) for the recorder unit at Base 1? What is the value for Base 2?
2. What is the pipeline value ( $\lambda T$ ) for the imaging unit at Base 1? What is the value for Base 2?

3. Complete this blank expected backorder/marginal return table using the METRIC model.

Base 1			Base 2		
Stock Level	R.Unit	I.Unit	Stock Level	R.Unit	I.Unit
0			0		
1			1		
2			2		
3			3		
4			4		
5			5		

Figure 5. Expected Backorders/Marginal Return Table

4. Complete this blank benefit-to-cost table using the values calculated in question three.

Base 1			Base 2		
Stock Level	R.Unit	I.Unit	Stock Level	R.Unit	I.Unit
0			0		
1			1		
2			2		
3			3		
4			4		
5			5		

Figure 6. Benefit-To-Cost Table

5. Given the \$25 base stock budget and your benefit-to-cost table, what is the best allocation of recorder and imaging units between the two bases?

	Base 1		Base 2		
Allocation	R. Item	I. Item	R. Item	I. Item	$\Sigma C S$ 1 1
1					
2					
3					
4					
5					
6					
7					

Figure 7. Item Allocation Table

6. What are the three purposes of the METRIC model?
7. What is the system objective of the METRIC model?

#### Case Number 5: Dyna-METRIC Model

Overview. The following scenario involves an F-16 squadron selected for deployment to a location that may place it in a potential combat environment. To evaluate its maintenance and supply support, the deploying squadron uses the Dyna-METRIC model.

The data used in this scenario were provided by Captain John Sullivan of the Air Force Institute of Technology (AFIT). Captain Sullivan has used an expanded version of this data while instructing LOG 290 (Combat Capability Assessment). These data are fictional and contain no classified information.

Situation. Moslem extremists operating out of eastern Turkey and northern Iran have been instigating political turmoil in the southwestern region of the Soviet Union for some time. Now, acts of sabotage are also happening. TASS and Pravda have reported that these foreign provocateurs are not only training anti-Soviet Arabs, but are also participating in the damaging raids. As a result of these raids, the Soviets have begun bombing the border regions. So far the bombing has been limited to Soviet territory but threats have been made to "strike the enemy where he lives." The increased tensions have forced the Turks to place their armed forces in an increased security posture. The Turks are also looking to the United States to be prepared to honor its NATO obligations should Turkey be attacked. The U.S., as a

result of the increased tensions, has airlifted tons of military equipment and supplies for the potential use of the Turkish armed forces. The Turks, however, seek more than equipment to defend against a superior opposing force. They want a greater display of American commitment to Turkish sovereignty, an increased American presence in the region. In particular, the Turks want more fighter aircraft to defend their airspace. After assessing the political situation, the U.S. announces that three stateside Air Force F-16 fighter squadrons will be rotated to American bases in Turkey to support an upcoming joint American-Turkish military exercise.

The commander of one of these selected squadrons is Major Mike Smith. Major Smith's squadron is composed of 24 aircraft. He is told, at a closed door pre-deployment briefing, that the probability for actual hostilities during his tour are high. Smith is instructed that he has carte blanche, as far as base resources go, in preparing for the move. When Major Smith returns to his squadron, the staff is assembled to begin planning for the rotation. The Major instructs them to assume combat situations will apply in all decisions. The required maintenance manpower and equipment are determined and plans for their shipment are formulated. Other required manpower (security and administrative) decisions are also made. Another important item to consider is what level of mission support the current stockage level of items in the War Readiness Spares Kit

(WRSK) will provide. The squadron's resource manager is instructed to meet with the base's supply and maintenance squadrons to answer this question, in view of:

1. The current item failure rates (per flying hour),
2. The deployed maintenance force's anticipated repair capability, and
3. Other possible expected repair capabilities.

The staff is provided with the expected flying hours per sortie and are given anticipated resupply times. To evaluate the potential effectiveness of the current deployable organization, given the expected environment of the deployment and the current WRSK stock levels, the Dyna-METRIC model is used.

Model Input Data. In the Dyna-METRIC input scenario, the unit deploys to one base, with no intermediate or depot repair capability. The time (administrative delay) needed to decide on the required repair level (to repair locally or declare the item as Not Repairable This Station (NRTS)) is set to zero. The deployment is expected to last for 30 days and a parts analysis is requested for days 1, 7, 15, 25, and 30 of the deployment. In Version 4.4 of the Dyna-METRIC model, there are 23 record options available. These options specify what output is desired for model analysis. The options selected for this scenario include option 8 (list problem LRUs) and option 11 (performance reports - based on input and previously purchased stock). Also, cannibalization at the

base level is authorized for SRUs and subSRUs (16:168-172). The flying program inputs for the deployment are summarized in Table V.

Table V  
Dyna-METRIC Model Input Data

<u>Days</u>	<u>Aircraft</u>	<u>Sorties/ Acft/ Day</u>	<u>Flying Hour/ Sortie</u>	<u>Maximum Sorties/ Acft/Day</u>
Peace	24	0.00	1.80	3.50
1- 7	24	3.20	1.80	3.50
8- 30	24	2.20	1.80	3.50

Furthermore, all assigned aircraft should be capable of performing any foreseeable mission with which the squadron might be tasked. The following tables reflect the data that was input for each of the WRSK items considered. These tables are approximations of the actual output tables one would receive from a Dyna-METRIC run.

Table VI is a listing of the detailed data input for the LRUs, SRUs, and subSRUs considered in the model. It consists of the national stock number for those parts input and their assigned item control designators (L 1 for the first LRU input, L 2 for the second, S 1 for the first SRU input, S 2 for the second, and so on). This table also includes the Centralized Intermediate Repair Facility (CIRF) test abilities, NRTS or condemnation requirements, and the cost for each of the items. Also included in this table are the current demands per flying hour for each item, its' lowest

level of repair authorized, and its' anticipated resupply time (shipping time from a CONUS depot).

Table VI

Dyna-METRIC Model:

Detailed LRU, SRU and SubSRU Information

<u>National Stock No.</u>	<u>Item *</u> <u>Number</u>	<u>Can Test</u> <u>at CIRF?</u>	<u>NRTS or</u> <u>Condemn</u>	<u>Cost (\$)</u>
1270010932256WF	L 1	Yes	After Test	87228
1270011022962WF	L 2	Yes	After Test	142290
1270011022963WF	L 3	Yes	After Test	142290
1270011022965WF	L 4	Yes	After Test	142290
1270011022966WF	L 5	Yes	After Test	142290
1630008521432	L 6	Yes	After Test	453
2620000524222	S 1	Yes	After Test	118
1630010389239	L 7	Yes	After Test	2605
2620010387026	S 2	Yes	After Test	152
1630011183642	L 8	Yes	After Test	9922
1630011069701	S 3	Yes	After Test	688
1630011069702	S 4	Yes	After Test	833
1630011069703	S 5	Yes	After Test	872
1630010844277	S 6	Yes	After Test	785
1660001952729	L 9	Yes	After Test	1185
2840011181064	L 10	No	After Test	1414
5821010369024	L 11	Yes	After Test	5177
5841010963945WF	L 12	Yes	After Test	23315
5865010441700EW	L 13	No	After Test	783
5865010540018EW	L 14	No	After Test	563
5895011126380	L 15	Yes	After Test	16103
6605010876645WF	L 16	Yes	After Test	167705
6610011190832	L 17	No	After Test	2149
6610011230046WF	L 18	Yes	After Test	21539
6645000763050	L 19	Yes	After Test	628

\* L = LRU  
S = SRU

Table VI (Continued)

Dyna-METRIC Model:

Detailed LRU, SRU, and SubSRU Information

Item Number		--Demands Per-- Flying Hour		Level of Repair	Resupply Time (Days)	
		Onshore	Offshore		Peace	War
L	1	0.00645	0.00645	Base	6.0	6.0
L	2	0.00351	0.00351	Base	6.0	6.0
L	3	0.00351	0.00351	Base	6.0	6.0
L	4	0.00351	0.00351	Base	6.0	6.0
L	5	0.00351	0.00351	Base	6.0	6.0
L	6	0.02587	0.02587	Base	6.0	6.0
S	1	0.01580	0.01580	CIRF	6.0	6.0
L	7	0.03704	0.03704	Base	6.0	6.0
S	2	0.03700	0.03700	CIRF	6.0	6.0
L	8	0.00309	0.00309	Base	6.0	6.0
S	3	0.00300	0.00300	CIRF	6.0	6.0
S	4	0.00300	0.00300	CIRF	6.0	6.0
S	5	0.00300	0.00300	CIRF	6.0	6.0
S	6	0.00300	0.00300	CIRF	6.0	6.0
L	9	0.01009	0.01009	Base	6.0	6.0
L	10	0.00183	0.00183	Base	6.0	6.0
L	11	0.00441	0.00441	Base	6.0	6.0
L	12	0.00445	0.00445	Base	6.0	6.0
L	13	0.01713	0.01713	Base	6.0	6.0
L	14	0.01430	0.01430	Base	6.0	6.0
L	15	0.00461	0.00461	Base	6.0	6.0
L	16	0.00505	0.00505	Base	6.0	6.0
L	17	0.00334	0.00334	Base	6.0	6.0
L	18	0.00280	0.00280	Base	6.0	6.0
L	19	0.00206	0.00206	Base	6.0	6.0

Table VII displays detailed repair data for the items shown in Table VI. There are four possible locations where repair can take place which are described in Table VII. Repair is considered at the base-level, at the CIRF-served base-level (colocated CIRF and base), at a CIRF in another location, and at the depot-level. Table VII lists the repair time (in days), the NRTS rates, and the condemnation rates for all four possible repair locations.

Table VII

Dyna-METRIC Model:

Base, CIRF, and Depot Related LRU, SRU, and SubSRU Data

Item Number	-----Lone Base-----			--CIRF - Served Base----		
	Repair Time (Days)	NRTS Rate	Condemn Rate	Repair Time (Days)	NRTS Rate	Condemn Rate
L 1	2.00	0.030	0	2.00	0.950	0
L 2	2.00	0.340	0	2.00	0.900	0
L 3	2.00	0.340	0	2.00	0.900	0
L 4	2.00	0.340	0	2.00	0.900	0
L 5	2.00	0.340	0	2.00	0.900	0
L 6	4.00	0.030	0	4.00	0.970	0
S 1	2.50	0.000	0	2.50	0.000	0
L 7	3.50	0.080	0	3.50	0.900	0
S 2	2.00	0.000	0	2.00	0.000	0
L 8	2.00	0.270	0	2.00	0.900	0
S 3	3.00	0.000	0	3.00	0.000	0
S 4	3.00	0.000	0	3.00	0.000	0
S 5	3.50	0.000	0	3.50	0.000	0
S 6	2.80	0.000	0	2.80	0.000	0
L 9	1.90	0.950	0	1.90	0.900	0
L 10	2.00	1.000	0	2.00	1.000	0
L 11	2.00	0.040	0	2.00	0.900	0
L 12	2.00	0.250	0	2.00	0.900	0
L 13	2.00	1.000	0	2.00	1.000	0
L 14	2.00	1.000	0	2.00	1.000	0
L 15	2.00	0.240	0	2.00	0.900	0
L 16	2.00	0.330	0	2.00	0.900	0
L 17	2.00	1.000	0	2.00	1.000	0
L 18	2.00	0.300	0	2.00	0.900	0
L 19	2.00	0.860	0	2.00	0.900	0

Table VII (Continued)

Dyna-METRIC Model:

Base, CIRF, and Depot Related LRU, SRU, and SubSRU Data

Item Number		-----CIRF-----			-----Depot-----		
		Repair Time (Days)	NRTS Rate	Condemn Rate	Repair Time (Days)	Repair Limit Per Day	Condemn Rate
L	1	2.00	0.000	0	2.00	9999.00	0
L	2	2.00	0.070	0	2.00	9999.00	0
L	3	2.00	0.070	0	2.00	9999.00	0
L	4	2.00	0.070	0	2.00	9999.00	0
L	5	2.00	0.070	0	2.00	9999.00	0
L	6	4.00	0.030	0	4.00	9999.00	0
S	1	2.50	1.000	0	2.50	9999.00	0
L	7	3.50	0.050	0	3.50	9999.00	0
S	2	2.00	1.000	0	2.00	9999.00	0
L	8	2.00	0.090	0	2.00	9999.00	0
S	3	3.00	1.000	0	3.00	9999.00	0
S	4	3.00	1.000	0	3.00	9999.00	0
S	5	3.50	1.000	0	3.50	9999.00	0
S	6	2.80	1.000	0	2.80	9999.00	0
L	9	1.90	0.120	0	1.90	9999.00	0
L	10	2.00	1.000	0	2.00	9999.00	0
L	11	2.00	0.020	0	2.00	9999.00	0
L	12	2.00	0.060	0	2.00	9999.00	0
L	13	2.00	1.000	0	2.00	9999.00	0
L	14	2.00	1.000	0	2.00	9999.00	0
L	15	2.00	0.050	0	2.00	9999.00	0
L	16	2.00	0.040	0	2.00	9999.00	0
L	17	2.00	1.000	0	2.00	9999.00	0
L	18	2.00	0.040	0	2.00	9999.00	0
L	19	2.00	0.100	0	2.00	9999.00	0

Please note that the depot assigned management responsibility for each item is normally an entry in this table. It was not included, however, since depot maintenance was not considered in the scenario.

Table VIII lists specific LRU information. This table displays the type of maintenance required (for example RR means Remove and Replace), what test equipment are assigned

for the item's repair, and what the variance to mean ratio for each item's pipeline quantity is. Whether or not this LRU can be cannibalized is also given in the table.

Table VIII

Dyna-METRIC Model:

Specific LRU Information

Number	Maint. Type	Assigned Test Equipment	Pipeline Variance To Mean Ratio	Cannibalize
L 1	RR	None	1.000	Yes
L 2	RR	None	1.000	Yes
L 3	RR	None	1.000	Yes
L 4	RR	None	1.000	Yes
L 5	RR	None	1.000	Yes
L 6	RRR	None	1.500	Yes
L 7	RRR	None	1.500	Yes
L 8	RRR	None	1.000	Yes
L 9	RR	None	1.500	Yes
L 10	RR	None	1.000	Yes
L 11	RR	None	1.000	Yes
L 12	RR	None	1.000	Yes
L 13	RR	None	1.500	Yes
L 14	RR	None	1.500	Yes
L 15	RR	None	1.000	Yes
L 16	RR	None	1.000	Yes
L 17	RR	None	1.000	Yes
L 18	RR	None	1.000	Yes
L 19	RR	None	1.000	Yes

Note: RR = Remove and Replace  
RRR = Remove, Repair, and Replace

In addition, this scenario requires some information not presented in Tables V-VIII. First, there were no test stands assigned. Second, the wartime demand rate multiplier used for both onshore and offshore deployments was one. Further, the sustained demand rates for both onshore and offshore were

zero. (In other words, these rates are assumed to be the same as during peacetime). Also, all LRUs are considered essential for an aircraft to be able to perform its missions.

Table IX lists how many of each LRU type are installed on an F-16 (Quantity Per Aircraft - QPA). The Minimum QPA category is the minimum number of each LRU that is required to be installed and functioning for an F-16 to fly. The Quantity Per Application (QPAp) category applies to SRUs. It indicates the number of SRUs there are for each LRU type.

Table IX

Dyna-METRIC Model:

Quantities Per Aircraft

Number		QPA	Minimum QPA	QPAp
-----		-----	-----	-----
L	1	1	1	---
L	2	1	1	---
L	3	1	1	---
L	4	1	1	---
L	5	1	1	---
L	6	1	1	---
S	1	1	---	1
L	7	2	2	---
S	2	2	---	1
L	8	2	2	---
S	3	2	---	1
S	4	6	---	3
S	5	2	---	1
S	6	4	---	2
L	9	1	1	---
L	10	15	15	---
L	11	1	1	---
L	12	1	1	---
L	13	1	1	---
L	14	1	1	---
L	15	1	1	---
L	16	1	1	---
L	17	1	1	---
L	18	1	1	---
L	19	1	1	---

An application fraction of one has been assigned to all LRUs. This indicates that all the LRUs in Table IX are used on each of the Squadron's F-16 aircraft.

Table X lists the initial stock levels of each item, how many units of each item would be available in a full F-16 WRSK kit.

Table X  
Dyna-METRIC Model:  
Initial Stock Levels

<u>Number</u>		<u>Level</u>	<u>Number</u>		<u>Level</u>
-----		-----	-----		-----
L	1	14	S	6	0
L	2	3	L	9	21
L	3	3	L	10	7
L	4	3	L	11	6
L	5	3	L	12	15
L	6	12	L	13	39
S	1	30	L	14	33
L	7	24	L	15	8
S	2	156	L	16	16
L	8	18	L	17	6
S	3	0	L	18	4
S	4	0	L	19	6
S	5	0			

Table XI is the Input Item Summary. It shows how many LRUs, SRUs, and subSRUs have been included in the model. For large groups of data, the program will partition the data into smaller groups. The amount of input data for this scenario was relatively small and did not warrant partitioning. Thus, the maximum group categories in the table reflect the total numbers of LRUs and SRUs originally input. The last set of categories describe the largest indenture relationships.

Table XI

Dyna-METRIC Model:

Item Input Summary

Total LRU Count	= 19
Total SRU Count	= 6
Total SubSRU Count	= 0
Maximum LRUs in a Group	= 19
Maximum SRUs in a Group	= 6
Maximum SubSRUs in a Group	= 0
Maximum SRUs to a LRU	= 4
Maximum LRUs to a SRU	= 1
Maximum SubSRUs to a SRU	= 0
Maximum SRUs to a SubSRU	= 0

The following tables detail the results derived from the input data. As stated before, the Squadron was interested in examining its expected performance based on WRSK kit support for days 1, 7, 15, 25, and 30.

Table XII displays the expected organizational performance. Normally the output is broken down into full and actual cannibalization categories. For this scenario, the full cannibalization output equalled the actual cannibalization output, so only the full cannibalization data is shown. The table displays the expected status of the organization for the days originally input. It gives us the calculated probability that less than 25% of the Squadron will be NFMC on the chosen date. It also shows the probability of achieving desired sortie objectives. Both of these probabilities are calculated within specified confidence limits. Table XII displays the expected number of

aircraft that will be available for the days requested (within an 80% confidence interval). It also shows the expected number (and fraction) of aircraft that will be NFMC. The next two categories of output in the table are the expected number of sorties for the requested status day and the expected number of sorties per aircraft that will be required to meet the total sortie requirement. The last column is the expected total number of backordered units among all the components.

Table XII

Dyna-METRIC Model:

Expected Organizational Performance

----- Full Cannibalization -----								
Day	Prob. < 25% NFMC	Prob. Achv. Sort.	FMC 80% Conf	Exp. E(NFMC)	Exp. Frac. NFMC	Exp. E(Sort)	Exp. Sort. /Acft	Total Back-orders
No.								
1	1.000	0.996	24	0.155	0.006	76.78	3.162	0.18
7	0.580	0.069	15	6.324	0.263	61.84	3.270	37.77
15	0.375	0.715	15	7.506	0.313	51.23	2.639	80.00
25	0.000	0.009	5	15.345	0.639	30.26	3.474	204.22
30	0.000	0.000	0	23.467	0.978	1.87	3.500	319.71

Twenty four F-16 aircraft were considered in the scenario. A target NFMC goal of 6 aircraft was established by the inputs. When the expected number of NFMC aircraft exceeds the target, the Dyna-METRIC program prints a Potential Problem Parts Report. As shown in Table XII, the first time this occurs is day 7. The Problem Parts Report (Table XIII) lists the worldwide and base-specific target and actual full cannibalization NMCS. It also lists the work unit code for that item as well as the name of the

test equipment that is required to fix the LRU. Note that the report covers both worldwide and base-specific data. By day 7 the squadron can expect at least five aircraft to be NMCS for NSN 1630010389239. Since the QPA for this NSN is two, they can expect around 10 backorders. Further, all 24 spares from the WRSK kit will have been used and 24 failed units will be undergoing repair.

Table XIII

Dyna-METRIC Model:

Potential Problem Parts Report for Day 7

----- Worldwide -----

NSN	LRU Number	Work Unit Code (WUC)	Name of Test Equip That Fixes LRU	I I I V Full Cann NMCS	Target Full Cann NMCS
1630010389239	L 7			5.2	6.0

----- Base-Specific Problem LRUs -----

Total Aircraft Which Use This LRU	QPA	Appli- cation Fraction	Variance To Mean Ratio	Total Spares (Stock Level)	Base Pipeline Quantity	Expected Back- orders
24	2	1.000	1.500	24	34.25	10.4

(Base-Specific continued)

Full Cann NMCS	Target Full Cann NMCS	Prob of Less or Equal To Targ Full Cann NMCS
5.2	6.0	0.639

As can be seen in Table XII, other problems also exist at day 7. There is a significant drop (from 1.0 to 0.580) in the probability of having less than 25% of the fleet NFMC. Correspondingly, there are also large drops in the expected number of FMC aircraft available and the probability of achieving the expected sortie requirements for day 7.

If the unit expects sustained combat throughout the entire 30 day period, then a combination of increased stock levels and/or increased maintenance capability is required to support the organization's mission. Another feature of Dyna-METRIC, not presented in the scenario, is when an organization inputs their mission requirements and the model outputs the stock levels required given the repair and resupply capabilities. As has been demonstrated, Dyna-METRIC can be a powerful tool in Air Force mission planning.

#### Case Questions.

1. The Dyna-METRIC model was developed to provide what kinds of information to improve logistics support?
2. What is one shortcoming of the model?
3. How does Dyna-METRIC view aircraft?

Case Number 6: Manufacturing Resource Planning (MRP II)

Overview. The purpose of a Manufacturing Resource Planning (MRP II) system is to effectively manage the resources of a manufacturing organization. It consists of a set of computer modules that link together the different functional areas of the organization. In MRP II, there are information flows between the manufacturing activity and the organization's purchasing, accounting, sales, maintenance, and engineering departments. This permits the company to simulate various resource (labor, plant capacity, etc.) and production plans to determine their effect on the organization as a whole.

With inputs from the various organizational functions, the MRP II system has the capability to accomplish the firm's: business planning, its sales and operations (production planning), master production scheduling, material requirements planning (MRP), capacity requirements planning, and execution of the support systems for shop floor control. From these computations and actions, MRP II generates integrated reports such as: the firm's business plan, a purchase commitment report, a shipping budget, an inventory projection in dollars, and other reports that reflect the firm's resource decisions (34:18).

Situation. In the last several years the Air Force has invested heavily in personal computers (PCs). These PCs are used by many organizations for word processing and database

management. The Air Force is presently searching for ways to use the power of these PCs to better control its inventory assets. The Air Force knows that with better forecasting and item management, it can perform its required missions more efficiently and with less on-hand stocks. One type of software package being considered for this purpose is the Manufacturing Resource Planning (MRP II) system. To evaluate MRP II's potential, the Air Force has decided to use it for managing the depot-level overhaul of a weapon system subassembly.

Model Input Data. The subassembly chosen by the Air Force for testing was landing gear. The site chosen for the test was the Maintenance Directorate at Ogden Air Logistics Center, Hill Air Force Base, Utah. In the test, MRP II is to be used for scheduling the depot level maintenance of F-4 main landing gear assemblies. To prepare for the test, the depot's maintenance capacity needs to be loaded into the MRP II system database (the number of servers available for landing gear maintenance and the manhour and equipment constraints involved). Other data that will be needed include the current fiscal year budget for this activity, as well as the inventory assets presently available and committed to this maintenance. The final pieces of data that will need to be input into the system are the engineering designs of the landing gear. Figures 8 and 9 are examples of a technical order (TO) description for an F-4 aircraft main

VOLUME FIGURE INDEX NO	DESCRIPTION						
	1	2	3	4	5	6	7
29	MECHANISM INSTL. MAIN LANDING GEAR SHRINK LH (SEE FIG 2-7-62 FOR NHA)						
	MECHANISM INSTL. MAIN LANDING GEAR SHRINK RH (SEE FIG 2-7-62 FOR NHA)						
1	LINK ASSY. MAIN LANDING GEAR UPPER SHRINK _____						
	(ATTACHING PARTS)						
2	BOLT, CRANK UPPER SHRINK LINK ATTACHMENT _____						
	WASHER (1 UNDER HEAD & 1 UNDER NUT) _____						
	NUT _____						
3	BOLT _____						
	BOLT _____						
	BOLT _____						
	WASHER (1 UNDER HEAD & 1 UNDER NUT) _____						
	NUT _____						
4	ROD END ASSY. MAIN LANDING GEAR UPPER SHRINK _____						
5	FITTING _____						
6	BEARING (81376) _____						
7	NUT _____						
8	ROD ASSY. MAIN LANDING GEAR UPPER SHRINK _____						
9	FITTING _____						
10	BEARING (81376) _____						
11	BELL CRANK ASSY. MAIN LANDING GEAR SHRINK LH (PARTS KIT AVAILABLE)						
11	BELL CRANK ASSY. MAIN LANDING GEAR SHRINK LH (PARTS KIT AVAILABLE)						
12	BOLT (KD) _____						
	WASHER (KD) _____						
	WASHER (KD) _____						
	NUT (72962) (MCDONNELL SPEC 3M221-4) (KD) _____						
13	BOLT (KD) _____						
	WASHER (KD) _____						
	WASHER (KD) _____						
	NUT (72962) MCDONNELL SPEC 3M221-21) (KD) _____						
14	FITTING (KD) _____						
15	BRUSHING (76301) (KD) _____						
16	PIN, CRANK _____						
17	WASHER SPECIAL _____						
18	NUT _____						
19	PIN _____						
20	BUSHING (KD) _____						
21	RING RETAINING (80756) (MCDONNELL SPEC 9M187-56) (KD) _____						
22	WASHER (KD) _____						
23	TRUNNION, MAIN LANDING GEAR SHRINK MECHANISM FITTING _____						
24	BUSHING, CRANK ASSY MAIN LANDING GEAR SHRINK (KD) _____						
25	BUSHING, SLEEVE (76301) (KD) _____						
26	BELL CRANK, L SIDE _____						
	BELL CRANK, L SIDE _____						
27	BELL CRANK, R SIDE _____						
	BELL CRANK, R SIDE _____						
	PARTS KIT, OVERHAUL, MAIN LANDING GEAR SHRINK BELL CRANK ASSY (763)						
28	LINK ASSY. MAIN LANDING GEAR LOWER SHRINK _____						
29	ROD END ASSY. MAIN LANDING GEAR LOWER SHRINK LINK _____						

Figure 8. Group Assembly Parts Listing

Mechanisms

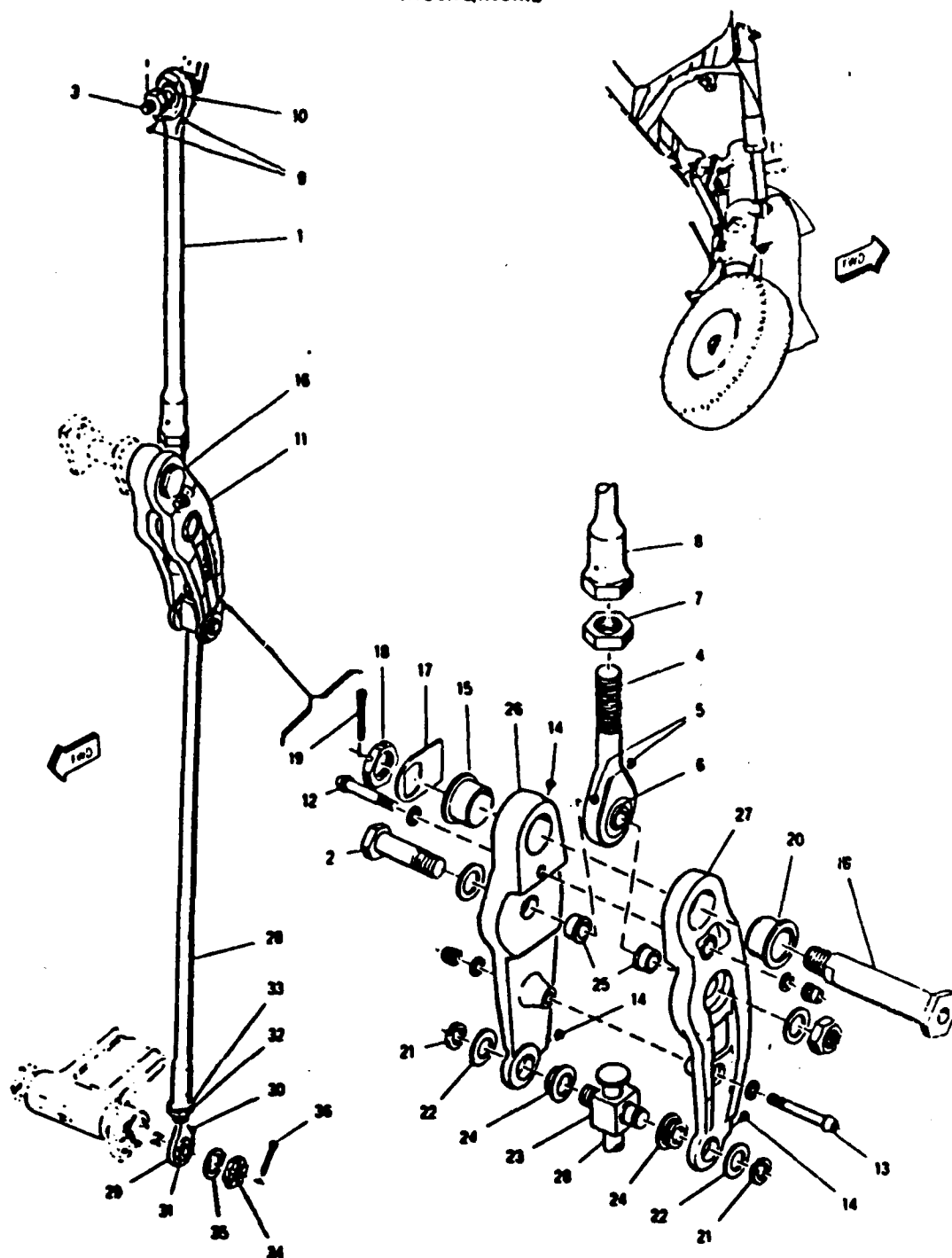


Figure 9. Illustrated Parts Breakdown (IPB)

landing gear shrink mechanism. The parts listing in Figure 8 can be used to determine the bill of material needed to perform the required maintenance. It also shows the indenture relationships of the parts that make up the complete shrink assembly. Those items with two dots next to their part name are components of the next higher assembly above them which has a single dot. The items with one dot next to their part name are the main components of the end-item in the drawing (which is the shrink mechanism itself). As can be seen in the parts listing, the necessary repair parts may also differ by aircraft model. All these items and their inter-relationships need to be entered into the MRP II system.

Once all the required data has been entered, the system is ready for activation. MRP II is capable of performing demand, supply, and capacity management throughout both the planning and execution phases. It is a closed-loop system that provides feedback to not only the Maintenance shops performing the work, but is also capable of providing Depot Supply with inventory status reports, providing Finance with up-to-date and projected dollar expenditures, and providing the Production Management with the necessary purchase requirements. Based on the number of incoming aircraft, MRP II can help Civilian Personnel determine if additional manpower should be added during peak periods or where to reassign manpower during slack periods. It can

also determine up-to-date customer delivery times based on the current status of the system or on where the system expects to be at some future point (based on manpower and parts availability).

There are two advantages that make the use of an MRP II system appear to be a wise decision. One, the MRP II system is an integrated package that can link all the various functions (Maintenance, Supply, Production Management, Civilian Personnel, and Finance) of the depot together. Through the use of PCs, any shop in the depot's Landing Gear Division can access the system and determine their upcoming workload and its priority. The second advantage of the MRP II system is that it is capable of providing each shop with feedback. If one shop makes changes to its scheduled inputs/outputs, other shops are able to evaluate how the changes will affect them.

Just the information flows within an MRP II system alone make it a valuable tool in a production-oriented environment. When you add in the enhanced ability to control assets, both in-work and scheduled, and to simulate various resource needs, it is easy to see the many advantages that MRP II offers the Air Force.

#### Case Questions.

1. What is one very important requirement for implementation of an MRP II system?
2. How does MRP II differ from MRP I?

3. What are three of the possible uses for an MRP system?
4. Given the partial Bill of Material (BOM) (Figure 10) for the L/H Main Landing Gear, complete the MRP worksheet.  
Should any Links be ordered? If so, when and how many?

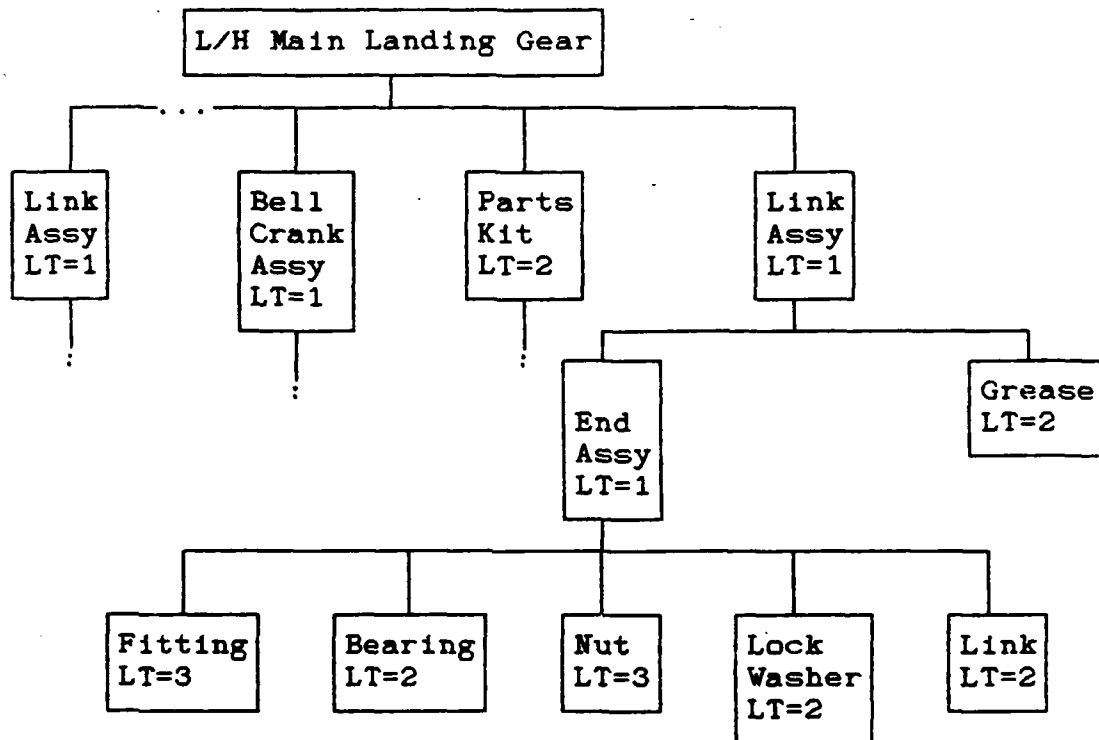


Figure 10. Partial L/H Main Landing Gear Bill of Materials

Week								
Wk	1	2	3	4	5	6	7	8

### Link Assy

Gross requirements		0	50	80	10	0	60	10	25
Scheduled receipts									
Projected on hand	15								
Net requirements									
Planned order receipts									
Planned order releases									

### Rod End Assy

Gross requirements									
Scheduled receipts									
Projected on hand	50								
Net requirements									
Planned order receipts									
Planned order releases									

### Link\*

Gross requirements									
Scheduled receipts		30			30				
Projected on hand	80								
Net requirements									
Planned order receipts									
Planned order releases									

\* Minimum Order Quantity = 30 each.

Figure 11. MRP Worksheet (31:346)

## Case Number 7: Bench Stock

Overview. A bench stock is a group of consumable items located in a maintenance work area. Bench stocks are created to insure that frequently used bits and pieces are readily available to support the maintenance work schedule. This arrangement is beneficial to both Base Supply and the supported maintenance organization. A few of these benefits are:

1. Required items are located near the user rather than in Base Supply.
2. The amount of communication and transportation between Base Supply and the maintenance activity is reduced (by consolidating materiel requests and deliveries).
3. Workloads for Supply are reduced because it can make less frequent bulk issues instead of more frequent individual issues.

To establish a bench stock, an organization must coordinate the request with the Bench Stock Support Unit (BSSU) and provide the space and personnel that will be required to support it (8:25-5 - 25-9).

The following scenario demonstrates how the bench stock system is a simple yet efficient approach towards inventory management.

Situation. During recent random testing of the fire alarms in Base Housing, it was discovered that 33 percent had

weak batteries which might fail during an actual fire emergency. Because of this, the Base Fire Marshall ordered a complete changeover of the units from battery to electric powered. The Base Civil Engineer (BCE) has been tasked with getting this job accomplished. There is currently a shortage of available electric fire alarm units at GSA depots. In fact, GSA advised the base that they will be receiving small lots of the units as they become available. The BCE wants to install the units as quickly as possible after receipt by Base Supply, and has coordinated with his Interior Electric and Carpentry Shops to ensure that sufficient manpower will be dedicated to this high-interest program.

SSgt. Johnson is the branch chief of the Carpentry shop. Upon examining the first of the new electric units received, he notes that the mounting screws that come with the new units are not adequate for the surfaces where the new units will be installed. To find the stock number of the screws he will need, SSgt. Johnson pulls out his GSA Supply Catalog. After locating the stock number (5305000129272, flat head screws), he contacts the Base Supply to determine the current availability of the item. Johnson is told that the item is currently zero balance, but one box (HD) was due-in to the Supply Organization.

Model Input Data. GSA has informed its customers that it may take up to three years to satisfy all of the requisitions for fire alarms. To ensure that the Carpentry Shop maintains

an adequate supply of the needed mounting screws, SSgt. Johnson has decided he must take two actions.

First, Johnson must work with Base Supply to ensure the Carpentry Shop has a ready reserve of the screws. To accomplish this he must submit a Minimum Reserve Authorization (MRA) to add the flat head screws to his bench stock. When this is approved, the MRA justifies maintaining at least a minimum level of the screws in SSgt. Johnson's bench stock.

The second action that SSgt. Johnson must do is to physically add a bin for the screws in his bench stock area. The bin must be large enough to hold the number of flat head screws on SSgt. Johnson's MRA. Also, the bin must be labelled with the national stock number, organizational/shop code, authorized quantity, item number, nomenclature and other indicative information. Maintaining an in-shop supply of the screws significantly increases SSgt. Johnson's ability to schedule fire alarm installations.

There are two types of bench stock special levels: Minimum Reserve Authorizations (MRAs) and Maximum Authorized Quantities (MAQs). These are the minimum and maximum levels for bench stock items. The type that SSgt. Johnson chose was an MRA based on a 60-day requirement. The unit of issue for the stock number was hundreds (HD) and he felt that if the Carpentry Shop could maintain a minimum level of two, it would adequately satisfy his requirements. To keep the

special level in effect, SSgt. Johnson will have to review the MRA level's amount semiannually with BSSU personnel and revalidate its requirement with them annually (8:25-21 - 22).

Bench stock levels can also be computed based on the stock number's consumption data. Essentially, the Base Supply computer calculates a 30 day average usage of the item based on the customer unit's past 180 days of demand history (8:25-7 - 13). This 30 day average value remains fixed unless there is a significant change in the item's consumption pattern. Here a significant change is defined as exceeding the square root of the current authorized quantity (8:25-24). In this case, the new requirement greatly exceeded previous demand history. Although, the stock number was loaded in the Supply computer, their current demand level for the item was one box (HD). Because of the limited past demand history, and the uncertain timing of future demand requirements, SSgt. Johnson had to choose between a Minimum Reserve Authorization (MRA) and a Maximum Authorized Quantity (MAQ). This item's low previous demand and its large unit of issue (HD), led SSgt. Johnson to choose an MRA of two. By selecting an MRA (or MAQ), the item will not be considered for deletion during M04, the Monthly Bench Stock Recommended Additions, Changes, and Deletions Report, computation. An item whose level is based on consumption, however, may be deleted automatically under program control if there are no demands within 270 days (8:25-7 - 13).

Case Questions.

1. Consider the flat head screws SSgt. Johnson added to his shop's bench stock. If the Carpentry Shop had ordered twelve boxes of these screws from Supply over the past 180 days, what would be the computed bench stock level?
2. Now that NSN 5305000129272 is in the Carpentry Shop's bench stock, shop personnel are finding many other uses for the flat head screw. Suppose consumption of the screw jumped to 24 boxes over the past six months. What would be the new computed bench stock level for the flat head screws in the Carpentry Shop?
3. Since MRA levels are based solely on a customer's perceptions of upcoming requirements, what is the impact of: 1) too small an MRA, and 2) too large of an MRA?
4. What are the different types of inventory models that are used at base-level by the USAF? Does it make sense to use several different types of models?

## V. Summary

### Chapter Overview

The purpose of this chapter is to summarize the research effort. The first section summarizes the objective of the research effort and the research methodology used. The second section briefly discusses the research effort itself. The third section is a conclusion. This section includes recommendations for future research.

### Summary of the Research Effort

This thesis is a companion work to a previous AFIT thesis accomplished by Major William C. Hood. Major Hood's thesis, A Handbook of Supply Inventory Models, described the various inventory models used in the Air Force. This thesis continued Major Hood's theme by adding examples of how the models are used in Air Force settings. These examples were designed to provide Air Force Supply personnel with easy to understand illustrations of how the models work.

The reporting methodology used was case studies. This method provided the greatest insight into how the models and their many components fit together and function. The data used in the case studies were primarily collected by observation. Offices within both Headquarters AFLC and the 2750th Base Supply were observed for this study.

## Research Summary

Seven specific models were presented in this study:

1. the Base Supply EOQ model,
2. the AFLC EOQ computation model,
3. the Repair Cycle Demand Level (RCDL) model,
4. the METRIC reparable model,
5. the Dyna-METRIC model,
6. the Manufacturing Resource Planning (MRP II) model,
7. and the Bench Stock computation model.

The components and elements that make up these models received a great deal of attention. To gain the best possible understanding of the models as a whole, it was important to understand their components. For all models, except Dyna-METRIC, the model's underlying mathematics were examined and explained.

The models were presented in case study form. For each case, a situation was given which had an Air Force application. The situation was then followed by a section of model input data. This data was the result of some action occurring in the presented scenario.

A series of questions followed each of the case studies. The questions were designed to highlight some of the important features of the models presented. Two examples of these questions are:

1. What are the advantages or disadvantages of a specific model's use?

2. Perform the mathematical calculations (using the presented model's input data) required by the model. The answers to the case study questions posed are listed in Appendix C.

### Conclusion and Recommendations

There is a void of information available to Air Force Supply personnel to demonstrate how inventory models may affect their decisions. Although the models presented are in fact computerized, their components are significantly impacted by the actions of Supply managers. The more knowledgeable Air Force Supply personnel become, the better the decisions they can make.

This study covered only seven of the many inventory models in-use in the Air Force today. Also, for the seven models that were discussed, it was not possible to cover every aspect that could have an effect on the model's performance. These two factors make follow-up studies in this area not only possible, but recommended. The specific recommendations from this study are:

1. Compile further examples of the models presented in this study. No single scenario can effectively highlight every aspect of any model.
2. Case studies should be accomplished for: 1) AFLC Depot Supply and Depot Maintenance models, 2) Medical Supply, 3) USAF Maintenance shop stock, 4) the LMI

Aircraft Availability Model, and 5) cross-service cases (for example - Army, Navy, DLA).

3. Lastly, use the cases presented in this thesis as training aids for AFIT course LOGM 628, Inventory Management. These case studies can be used to reinforce the course's inventory model presentations.

Appendix A: Abbreviations and Acronyms

BO	= Backorder
$C_B$	= Backorder cost per unit
$C_H$	= Holding cost per unit
$C_O$	= Cost per order
$C_U$	= Cost per unit
D	= Annual demand or Expected annual demand
d	= Lead-time demand
$\bar{d}$	= Expected lead-time demand
DDR	= Daily Demand Rate
DDT	= Depot Delay Time
EBPC	= Expected backorders per cycle
FR	= Fill Rate
LT	= Lead-time
MRP	= Material Requirements Planning
MRP II	= Manufacturing Resource Planning
N	= Number of operating increments (days, weeks, etc.)
NRTS	= Not Repairable This Station
OST	= Order and Ship Time
PBR	= Percentage of Base Repair
Q	= Economic order quantity
R	= Reorder point
RCT	= Repair Cycle Time
S	= Units backordered
SDT	= Expected delay due to nonavailability of an SRU

SLQ     = Safety Level Quantity  
SS       = Safety Stock  
TC       = Total cost  
V        = Maximum inventory  
DDR      = Daily demand rate  
VOD      = Variance of demand  
VOO      = Variance of order and ship time

## Appendix B: Definitions

Backorder (B/O): An obligation, assumed and recorded by any level of Supply, to issue at a later date a requisitioned item which was not available for immediate issue. [1]

Bill of Material (BOM): A listing of all the subassemblies, intermediates, parts, and raw materials that go into a parent assembly. [2]

Demand: A request submitted to support managers for supplies and/or equipment. [1]

Economic Order Quantity (EOQ): A variable requirement for an economic order and stockage program (EO&SP) item which is computed as a function of the cost to order, the cost to hold, the unit price, and the annual requirements rate. [1]

Lead-time: In a logistics context, the time between recognition of the need for an order and the receipt of the goods. Individual components of lead-time can include: order preparation time, queue time, move or transportation time, receiving and inspection time. [2]

Manufacturing Resource Planning (MRP II): A method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer "what if" questions. It is made up of a variety of functions, each linked together: business planning, sales and operations (production planning), master production scheduling, material requirements planning, capacity requirements planning, and the execution support systems for capacity and material. Output from these systems would be integrated with financial reports such as the business plan, purchase commitment report, shipping budget, inventory projection in dollars, etc. Manufacturing resource planning is a direct outgrowth and extension of closed-loop MRP. [2]

Material Requirements Planning (MRP): A set of techniques which uses bills of material, inventory data, and the master production schedule to calculate requirements for materials. It makes recommendations to release replenishment orders for materials. Further, since it is time phased, it makes recommendations to reschedule open orders when due dates and need dates are not in phase. [2]

Order and Ship Time (OS&T): The time interval in days between the initiation of stock replenishment action by a specific activity and the receipt by the base of the materiel resulting from such action. Also referred to as pipeline time. [1]

Pipeline Stock: Inventory to fill the transportation network and the distribution system including the flow through intermediate stocking points. The flow time through the pipeline has a major effect on the amount of inventory required in the pipeline. Time factors include order transmission, order processing, shipping, transportation, receiving, stocking, etc. [2]

Safety Stock: A quantity of stock planned to be in inventory to protect against fluctuations in demand and/or supply. [2]

War Reserve Materiel (WRM): The materiel required to supplement peacetime assets to completely support the forces, missions, and activities reflected in USAF war plans. [1]

War Readiness Spares Kit (WRSK): A kit consisting of selected spares and repair parts required to sustain operations (without resupply) at a base, a deployed location, or a dispersed location for the first month of conventional activity as projected in USAF war plans. [1]

[1] These definitions were taken from AFM 67-1, Vol II, Part 2, Chapter 3.

[2] These definitions were taken from The Official Dictionary of Production and Inventory Management Terminology and Phrases, Sixth Edition.

Appendix C: Suggested Answers to Chapter IV Questions

Case 1: Base Supply EOQ Model

Question 1:

Local purchase:

$$= \frac{16.3 \sqrt{(70)(2.75)}}{2.75} = 82.238 \text{ or } 83 \text{ units.}$$

Non-local purchase:

$$= \frac{8.3 \sqrt{(70)(2.40)}}{2.40} = 44.825 \text{ or } 45 \text{ units.}$$

Question 2:

Safety Level Quantity:

$$= 1 \sqrt{(30)(12) + (.192)^2 (20)} = 18.9 \text{ or } 19 \text{ units.}$$

Reorder Level:

$$\text{OSTQ} = (.192)(30) = 5.76 \text{ or } 6 \text{ units.}$$

$$\text{Reorder Level} = 6 + 19 = 25 \text{ units.}$$

Economic Order Quantity Demand Level:

$$\begin{aligned} &= \text{TRUNC} [ 44.825 + 5.76 + 18.99 + 0.999 ] \\ &= \text{TRUNC} [ 70.574 ] \\ &= 70 \text{ units.} \end{aligned}$$

Question 3:

On the surface the idea of being able to purchase more locally sounds like a good idea. However, as was seen in the two EOQ computations the economical buy quantity for local

purchase is nearly double the depot buy amount exceeds the annual demand. What might happen is that in decreasing depot stocks and costs, base stocks and its resulting costs would rise to a new level where the new total costs curve would be its lowest point. The depot would actually just be passing its costs and responsibilities down the chain. For some items, price (cost) alone may not provide a sufficient answer concerning the value of a local buy. The base may have to evaluate such an item on the merit of, "what will be the value of the increased customer service that is derived by locally purchasing the item from a stable local vendor?". These items would have to be considered on a case-by-case basis.

For the item discussed in this case study, keeping the depot as the primary source of supply would probably be the best choice. With depot buys of this item, the safety level quantity is 19 units while the order and ship time quantity is only 6 units. Also, the EOQ for a depot buy is only 45 units. These are far below the 83 units suggested by the local purchase EOQ buy.

Case 2: AFLC EOQ Model

Question 1:

$$LT = 4.24 + 7.23 = 11.47$$

$$\theta = 1.032 * .5945 * 10.38 * (.82375 + .42625 * 11.47)$$

$$\theta = 36.38$$

Question 2:

$$K = -.707 \ln \left[ \frac{2 \sqrt{2} * (.1) * 138 * \sqrt{11.70}}{45 * \frac{1}{4} * 36.38 * (1 - \exp(-\sqrt{2} * \frac{138}{36.38}))} \right]$$

$$K = .78926$$

Question 3:

$$SL = .78926 * 36.38$$

$$SL = \text{TRUNC}(28.711) = 28 \text{ units.}$$

Question 4:

$$\text{Stock} = SL + OST + EOQ = 28 + 11 + 138 = 177 \text{ units}$$

Case 3: Repair Cycle Model

Question 1:

$$PBR = \frac{12 * 100}{12 + 4} = \frac{1200}{16} = 75 \text{ percent or } .75$$

Question 2:

$$OSTQ = .0328 * 20 * (1 - .75) = 0.164 \text{ units}$$

Question 3:

$$RCQ = .0328 * (30 / 12) * .75 = 0.062 \text{ units}$$

Question 4:

$$NCQ = .0328 * (5 / 4) * (1 - .75) = 0.010 \text{ units}$$

Question 5:

$$\begin{aligned} SLQ &= 1 * \sqrt{3 * (.062 + .010 + .164)} \\ &= .8414 \text{ units} \end{aligned}$$

Question 6:

$$\begin{aligned} S &= .062 + .164 + .010 + .8414 + .5 \\ &= \text{Trunc } [1.5774] \\ &= 1 \text{ unit} \end{aligned}$$

Case 4: METRIC Model

Question 1:

Base 1- recorder unit =  $.4[(1.0 \times 5.0) + 0.0(20.0 + 10.0)] = 2$

Base 2- recorder unit =  $.4[(0.9 \times 5.0) + 0.1(20.0 + 10.0)] = 3$

Question 2:

Base 1- imaging unit =  $.4[(0.8 \times 5.0) + 0.2(20.0 + 10.0)] = 4$

Base 2- imaging unit =  $.4[(0.9 \times 5.0) + 0.1(20.0 + 10.0)] = 3$

Question 3:

The completed Expected Backorders/Marginal Return Table:

Base 1			Base 2		
Stock Level	R. Unit	I. Unit	Stock Level	R. Unit	I. Unit
0	2.000	4.000	0	3.000	3.000
1	1.135	3.018	1	2.049	2.049
2	.541	2.109	2	1.249	1.249
3	.218	1.348	3	.672	.672
4	.075	.781	4	.319	.319
5	.022	.410	5	.135	.135

Question 4:

The completed Benefit-To-Cost Table:

Base 1			Base 2		
Stock Level	R. Unit	I. Unit	Stock Level	R. Unit	I. Unit
0	.288	.246	0	.317	.238
1	.198	.227	1	.267	.200
2	.108	.190	2	.192	.144
3	.048	.142	3	.118	.088
4	.018	.093	4	.061	.046
5	.005	.054	5	.028	.021

Question 5:

The completed Item Allocation Table:

	Base 1		Base 2		
Allocation	R. Item	I. Item	R. Item	I. Item	EC S i i
1	0	0	1	0	3
2	1	0	1	0	6
3	1	0	2	0	9
4	1	1	2	0	13
5	1	1	2	1	17
6	1	2	2	1	21
7	1	2	2	2	25

Question 6:

1) To determine the optimal base and depot stock levels for each item, given a budget constraint or system performance.

2) To take fixed stock levels and optimally allocate the stock between the bases and the depot.

3) To provide an assessment of the performance and investment cost for the system of any allocation of stock between the bases and depot (27:123).

Question 7:

To minimize the expected number of backorders.

Case 5: Dyna-METRIC Model

Question 1:

1. Operational performance measures.
2. Effects of wartime dynamics.
3. Effects of repair capacity and priority repair.
4. Problem detection and diagnosis.
5. Spares requirements (16:1).

Question 2:

1) A shortcoming of the model is that "input" sorties break parts, not "flown" sorties. Because of this, the model could break more parts than would occur in the "real" world.

2) The output from the Dyna-METRIC model is only as accurate as the data input. Inaccurate data can lead to over- or understated Squadron performance (conclusion from Coronet Warrior I).

Question 3:

Dyna-METRIC sees the entire aircraft as a collection of LRUs. Because of this, aircraft availability is modeled as a direct function of the availability of the aircraft's LRUs.

Case 6: MRP II

Question 1:

Because they are large complex systems, they require extensive computing facilities and accurate data bases to effectively do their job (18:412).

Question 2:

MRP I is a production and inventory control system used for scheduling and materials management. MRP II uses MRP I and adds to the system the information needed from and by engineering, maintenance, accounting, purchasing, sales, and other functions that interface with manufacturing (18:274).

Question 3:

- 1) Inventory control (time phasing orders according to needs).
- 2) Scheduling (setting priorities based on what we need and when).
- 3) Capacity requirements planning (determining if the the system can handle a planned production schedule) (31:373-374).

Question 4:

The completed MRP Worksheet:

Week								
Wk	1	2	3	4	5	6	7	8

Link Assy

Gross requirements		0	50	80	10	0	60	10	25
Scheduled receipts									
Projected on hand	15	15	0	0	0	0	0	0	0
Net requirements			35	80	10		60	10	25
Planned order receipts									
Planned order releases		35	80	10		60	10	25	

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Gross requirements		35	80	10		60	10	25	
Scheduled receipts									
Projected on hand	50	15	0	0	0	0	0	0	0
Net requirements			65	10		60	10	25	
Planned order receipts									
Planned order releases		65	10		60	10	25		

Link\*

Gross requirements		65	10		60	10	25		
Scheduled receipts		30			30				
Projected on hand	80	45	35	35	5	0	0	0	0
Net requirements						5			
Planned order receipts									
Planned order releases				30					

\* Minimum Order Quantity = 30 each.

Case 7: Bench Stock

Question 1:

$$\frac{12 \text{ boxes}}{6 \text{ months}} = 2 \text{ boxes/month}$$

So, the computed bench stock level is 2 boxes.

Question 2:

$$\frac{24 \text{ boxes}}{6 \text{ months}} = 4 \text{ boxes/month}$$

The change between the old and new bench stock levels is 2 boxes. Since the square root of the old level is 1.414 and this amount is less than the change in the computed bench stock levels (2), the new M04 will have an updated bench stock level of 4 boxes.

Question 3:

1) Too small an MRA could lead to shortfalls in mission support. Also, lost lead-time in placing orders could cause "emergency" high priority requisitions to be submitted.

2) Too large an MRA unnecessarily ties up limited customer budgets in excess inventory. Even if a customer returns the excess to Supply, there is no guarantee that they'll receive a credit to their account.

Question 4:

- Repair Cycle, EOQ, Bench Stock

- It makes sense according to ABC analysis. Repair cycle items represent the bulk of the Air Force's total annual inventory investment. As a result, the models that apply to the repair cycle items (for example, METRIC), track this inventory far more closely than do the models used for EOQ or bench stock items. EOQ items represent the next largest inventory investment block. They in turn, are given more attention than are bench or shop stock items.

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The purpose of this thesis was to develop case study examples of Air Force Supply inventory models. It is intended to be a companion work to a previous AFIT thesis, A Handbook of Supply Inventory Models, by Major William C. Hood. Together, these two works are to be used by Air Force Supply personnel to gain an understanding of how the various Supply inventory models work.

These case studies are composed of detailed scenarios which highlight the components and functions of the models presented. All scenarios use Air Force data/situations in their presentation. Following each scenario is a series of questions about the situation presented, or about the model being used, which are designed to increase the understanding and comprehension concerning some aspect of the model's ability or performance.

The inventory models presented in this study are:  
1) the Base-level EOQ model, 2) the AFLC EOQ model,  
3) the Repair Cycle Demand Level model, 4) the Multi-Echelon Technique for Recoverable Item Control (METRIC) model, 5) the Dyna-METRIC model, 6) the Manufacturing Resource Planning model, and 7) the Bench Stock model.

*Inventory models, logistics management, (etc)*

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